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Technical Note 1975-14

M. E. Austin

The ARIES Program: A General Overview and Users' Guide

10 December 1975

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MASSACHUSETTS INSTITUTE OF TECHNOLOGY

LEXINGTON, MASSACHUSETTS

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This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

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LINCOLN LABORATORY

THE ARIES PROGRAM: A GENERAL OVERVIEW AND USERS' GUIDE

M. E. AUSTIN

Division 3

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ABSTRACT

ARIES is a system simulation computer program developed by Lincoln Laboratory to study radar tracking and command-guided intercepts in a realistic radar environment. This report is the first in a series of three, and provides a broad operational perspective on the ARIES Program while avoiding those mathematical details to be found in subsequent reports in the series. Model parameters and options available to the engineer are presented, together with sufficient program structure and control information to enable a programmer to execute the ARIES Program.

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SECTION 1--INTRODUCTION

ARIES is a system simulation computer program developed by Lincoln Laboratory to study radar tracking and command-guided intercepts in a realistic radar environment. Written in FORTRAN and designed for execution on the CDC 6600 computer, it has considerable versatility in the specification of radar, target, tracking and environmental models.

1.1 Program Purpose

ARIES is designed to be a useful analytical tool for several allied areas. Originally ARIES was used in the strategic BMD area to estimate the metric state vector (position and velocity) of tracked targets, and then to extrapolate ahead in time to determine an intercept point for an ICBM. The radar measurements were subject to environmental effects which were reflected in the intercept miss distances. Refraction and scintillation models were used in ARIES, and the effects of various calibration schemes on target location accuracies were studied. ARIES was also used to study the problem of multipath in low angle tracking and to examine the effectiveness of various proposed schemes to overcome degradations in prediction caused by multipath. The use of ARIES in BMD studies was terminated in the summer of 1974.

More recently, a modified endoatmospheric version of ARIES, known as the HWLPTR (Hostile Weapons Location Projectile Tracking Radar) Program, has been used in the tactical area for the evaluation of a radar's performance in "backtracking" an incoming artillery or mortar shell to determine its point of firing. The resulting point estimation error CEP values also assist in the evaluation of the drag model error effects and in the study of the overall performance of hostile weapon location systems.

1.2 Program Features

Since the ARIES Program provides a fairly elaborate system simulation, it is useful to tabulate the various features incorporated in ARIES. The major components of the simulation are summarized below:

1. Target trajectories---accepts input of target state vectors in several coordinate systems. Trajectories with launch angle, reentry angle or minimum energy constraints from a given launch location to an impact point are also available.
2. Radar models---both mechanically steered (dish) and phased array radars are modeled. Radar sensitivity, beamwidth, frequency and location are specified by inputs. Range and angle measurement precision are also specified by inputs.
3. Radar measurement modeling
   a. Target modeling---static cross-section measurements on real targets are used in conjunction with rigid body dynamics (Euler's equations) to obtain realistic dynamic RCS simulations. Constant and sinusoidal, as well as an analytic cylinder, RCS options are also available.

b. Noise and propagation effects---radar measurements are corrupted by receiver noise (S/N dependent), range-independent noise effects (jitter, quantization, etc.) and uncorrected propagation effects. Tropospheric and ionospheric refraction are assumed to be corrected to within random percentages (input parameters) of the true values. Ionospheric scintillation and multipath effects corrupt the data but are assumed to be uncorrected in the measurement model.

4. Trajectory estimation (Target Tracking)---Maximum Likelihood Estimation (MLE) of the target trajectory is performed based on measurement data collected at specified PRF's over specified track intervals. Individual measurements are weighted according to their measurement variances. ARIES could be easily extended to use recursive tracking algorithms.

5. Target Discrimination---(Not presently implemented.) Conceptually, discrimination algorithms would be implemented to determine whether a particular simulated target constituted a threat to the defended area.

6. Interceptor modeling---(Not presently implemented.) Flight characteristics of one or more interceptor types would be utilized to conduct a command-guided intercept. Currently, the program extrapolates the estimated and true target state vectors to various time (or altitude) points after termination of track to obtain miss

distances. Miss distance statistics are computed from the accumulated miss distances observed on a series of Monte Carlo tests.

In addition to the above simulation components, ARIES also accommodates multiple radars, multiple targets and multiple track intervals on a given simulation run. The feature of making many Monte Carlo runs for a given scenario permits the generation of meaningful miss distance statistics. A building block/subroutine program structure lends itself to reasonable straightforward modifications of or additions to the program.

The input/output of the ARIES Program is engineer oriented. For input, simulation data cards are conveniently grouped into "packets" (each packet defines a target model, a radar model, an environmental model, etc.) which the engineer may simply stack up, together with packets specifying the desired simulation "scenario". For output, an 8½" x 11" ARIES Test Report (see Appendix) is generated which provides the engineer with descriptions of his input model parameters and scenarios, along with the resultant simulation data and statistics. The outputs are all organized into logical sections which are indexed for ready reference. Outputs from ARIES also include trajectory plots superimposed on a world map, plots of true and measured target cross-section, and a radar measurements tape containing metric and RCS data for processing by other programs.

1.3 Program Documentation

The ARIES Program is documented in three separate Lincoln Laboratory Technical Notes as follows:

1. The ARIES Program - A General Overview and Users' Guide
2. The ARIES Program - Coordinates, Transformations, Trajectories and Tracking
3. The ARIES Program - Analysis and Generation of Simulated Radar Measurements

The first report presents a general discussion of the ARIES Program, including the logical organization of the program and descriptions of all subroutines. All of the options available to a user are discussed and the methods of setting up the input "packets", including controls to activate the various options, are presented. Program output, including typical pages from an actual ARIES Test Report, is discussed in this first volume.

The second and third volumes contain all of the relevant mathematics and the models used in ARIES. Most of the deterministic mathematics (coordinate systems and transformations, trajectory generation, estimation algorithms, miss distance calculations, etc.) are in the second report (reference 1). The third report is primarily concerned with the generation of radar measurements, including the corruptive effects of noise, radar biases, propagation and time-varying radar cross-section (reference 2).

1.4 Organization of This Report

Section 2 explains briefly in general terms those user-specified parameters required to describe each type of ARIES model (target models, radar models, etc.), as well as those simulation controls and edit controls required in the execution of an ARIES Test Run.

The structure of the ARIES Program is described in Section 3, while the contents of its principal output, the ARIES Test Report, are described in Section 4. Detailed parameter and format information for executing ARIES are given in Section 5. The Appendix contains typical pages from actual ARIES Test Reports, serving to illustrate the descriptions of Section 4.

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SECTION 2--ARIES TEST RUNS

Preparation of the input cards and the execution of the ARIES program is termed an "ARIES Test Run". As indicated in Figure 2.1, such a run requires the user to specify models and definitions of the various components of a mission, and to define by a "simulation scenario" the manner in which he desires these components to interact with one another. The principal output of an ARIES Test Run is a document known as an "ARIES Test Report", which is described in detail in Section 4 of this Note, and an example of which is given in the Appendix. Selected RCS and Metric information for subsequent processing by other programs may also be output, at the user's option. The contents of the ARIES Test Report are subject to user-specified edit controls. It is the purpose of the present section to explain these user-specified models, definitions, scenario and edit controls in somewhat general terms, leaving the detailed descriptions of parameters and options for Section 5.

2.1 Target Models

In the ARIES program a target model must include two types of information: "metric" and "RCS" (radar cross-section). By "metric" information we mean whatever is required to completely determine the target's position at each point in time along its trajectory. By "RCS" information we mean whatever is required to completely determine the target's orientation in space at each point and time, and to determine its radar cross-section for all orientations.

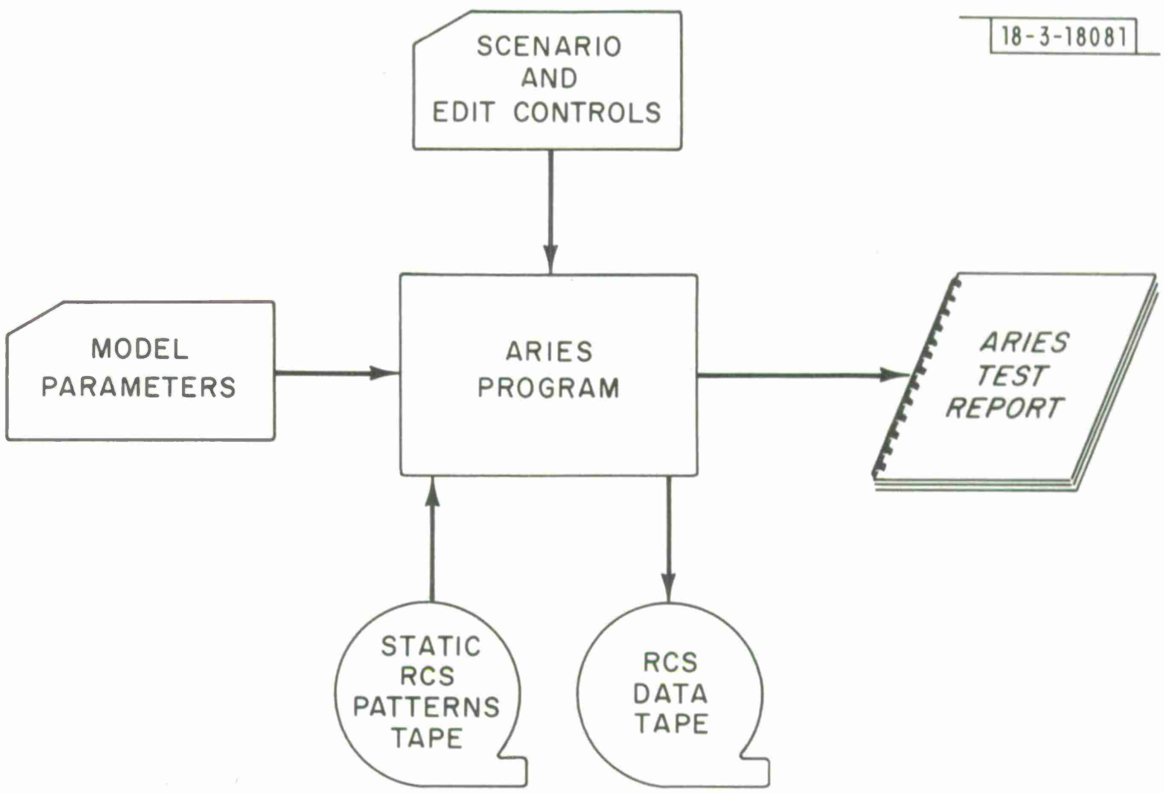


Fig. 2.1. Components of an ARIES Test Run

2.1.1 Metric Information

ARIES metric information on a target may be input in one of two basic ways. The simplest way is to specify a conventional 7-component metric state vector:

Time-of-validity
Coordinate 1 position
Coordinate 2 position
Coordinate 3 position
Coordinate 1 rate
Coordinate 2 rate
Coordinate 3 rate

where any one of several radar-centered or ECI coordinate systems may be chosen as explained in Section 5.

The second way of providing a target's metric information is to specify its launch and impact points. Under the ARIES "launch-impact" options

Longitude
Geodetic Latitude
Height

must be specified for both the launch and impact points (where all quantities are defined with respect to the ARIES Ellipsoidal Earth Model discussed in Reference 1, Section 2.1). Since it is possible to fit any number of physical (ballistic) trajectories through a pair of launch and impact points, then in addition ARIES requires that one of the following options be specified:

Minimum Energy Trajectory Option
Specified Reentry Angle Option
Specified Launch Angle Option

No matter how the target's metric information is input to ARIES, it is immediately converted into a metric state vector in ECI coordinates prior to its use by the ARIES program. Discussions of ARIES coordinate systems, transformations, and the techniques used in the determination of trajectories for the launch-impact option are to be found in Reference 1.

For endoatmospheric targets, a drag model (Coefficient-of-drag as a function of Mach number) must also be input. For artillery projectiles a basic drag table is built into ARIES, and the user need only supply the diameter and weight of the shell, plus a "drag table uncertainty" number to account for round-to-round variations in projectile weight, etc.

2.1.2 RCS Information

The orientation of an exoatmospheric ballistic target at any time is determined in ARIES from the Euler angles of its principal body axes and its tumble rates about those axes at a specified point in time:

Time of Validity
Euler Angle 1
Euler Angle 2
Euler Angle 3
Spin rate about axis 1
Spin rate about axis 2
Spin rate about axis 3

Moment-of-inertia about axis 1
Moment-of-inertia about axis 2
Moment-of-inertia about axis 3

where the Euler angles are measured with respect to a specified coordinate system (there are two options, explained in Section 5.3). A target's radar cross-section (RCS) is obtained via table-look-up in static RCS pattern tables. The program has tables alloted for principal and orthogonal polarization radar return amplitudes and phases.

The user must define (with code) the inventory of patterns available from tape or mass storage in the initialization routine INITAL. At execution time the sections of the static pattern inventory associated with the target types selected must be attached to the program in order to bring the data into fast storage.

The chain of events is:

1) Inventory Content Defined (Subroutine INITAL)
2) Test for static pattern request and User's request (Subroutine RCSETP)
3) Locate, read, and pack into core the new RCS table. (Subroutine RDIN)

There are also special target options available (sphere, cylinder, etc.), as explained in Section 5.3. For a detailed discussion of how this target orientation computation is performed, see Reference 2, Section 7.

While ARIES RCS tables in general may contain both principal polarization amplitude and phase and opposite polarization amplitude and phase, some tables may only contain amplitude information. Entering these tables with aspect and roll angles of the target with respect to a radar, ARIES determines the RCS information required. Special symmetry codes also allow for shorter tables for bodies which exhibit RCS symmetries. These symmetry codes are explained in Section 7.5 of Reference 2.

2.2 Environmental Models

The environmental models currently incorporated into ARIES include:

Tropospheric Refraction
Ionospheric Refraction (daytime, nighttime)
Ionospheric Scintillation
Multipath Reflections

Use of these models is explained in Section 5 while their mathematical details are discussed in Reference 2.

In addition to the above models, two other models, barium clouds and nuclear clouds, were among those environmental models being considered as possible future additions to ARIES (Reference 3).

2.2.1 Tropospheric Refraction

The tropospheric refraction effects are obtained from table-look-ups where the entries are elevation angle and altitude. Range and elevation perturbations due to tropospheric refraction are first looked up as a function of target elevation and then multiplied by a factor which is obtained by a second table-look-up based on target altitude. An example table is shown on page 14 of the Appendix. The tables shown there have the input elevation in milliradians, the perturbation in range in meters, and the perturbation in elevation in milliradians. The input altitude is listed in kilometers, the "factors" are dimensionless. This particular table - except for the units involved - is the one obtained from a General Electric Company ray-tracing program. ARIES allows for incorporating other types of tropospheric refraction tables, such as those used by the KREMS radars on Roi-Namur, Marshall Islands, but at present only the G.E. table is available.

2.2.2 Ionospheric Refraction

There are presently two ionospheric refraction models available in the ARIES program, one for daytime, one for nighttime. Both are obtained in the same manner as the tropospheric refraction. Again ARIES uses sets of tables, with the elevation and altitude of the target as input variables. Based on the target's elevation the first table gives perturbations in range and elevation, which are then multiplied by factors which are looked up as a function of the target's altitude. An example of these two tables is shown in the Appendix, pages 16, 17. These ionospheric refraction tables - except for the units involved - were taken from the G.E. RAMIE program.

2.2.3 Multipath Models

The mathematics of the two-path multipath model are described in Reference 2, Section 6. There are two table-look-ups involved; one to get a reflection coefficient as a function of elevation, the other to obtain a sidelobe level, also as a function of elevation. A standard antenna pattern, in the form of a sidelobe level table for a ½° beamwidth is built into ARIES (the table is shown in the Appendix, page 19). For other radar beamwidths this sidelobe pattern is scaled appropriately, as described in Section 6 of Reference 2.

2.3 Radar Models

ARIES allows for two types of radar models; dish type radars measuring range, azimuth and elevation (RAE) and phased-array radars measuring range and direction cosines (RUV). No matter which type of radar model is selected, the radar's location on the ellipsoidal earth model must be specified, in addition to the radar's sensitivity, noise parameters, type of tracker, radar beamwidth and frequency.

2.3.1 Radar Location

The location of a radar is input in terms of the ARIES earth model, requiring its longitude, geodetic latitude and height above the ellipsoidal earth model surface. For a detailed description of the ARIES earth model, see Reference 1, Section 2.

2.3.2 Radar Noise Parameters

There are three types of parameters which are assumed to corrupt the radar measurements used in ARIES. The first are radar biases. These occur in range, azimuth, elevation for a dish RAE radar, and they occur in range, U and V for a phased-array RUV radar. The U and V biases are input for a measurement made along the normal to the phased array, and are modified appropriately for off-normal targets (as explained in Section 3 of Reference 2). In addition to the biases, the same coordinates are assumed to have noise components due to thermal noise in the receiver, and jitter noise (allowing for quantization in the A/D converters, etc.) (also discussed in Section 3 of Reference 2). Thus the three types of radar noise parameters input to ARIES radar models are: biases, thermal, and jitter noises.

2.3.3 Radar Tracker Type

ARIES is designed to allow for different radar tracker options (such as α-β trackers, recursive filters, etc.). At present, however, only a maximum-likelihood-estimator, or MLE, (known as tracker type 1) is available. This estimator fits a physical trajectory through all of the measurements at the end of the requested "track" interval (or intervals) as explained in detail in Section 7 of Reference 1. The tracking problem itself is not really addressed by the MLE tracker, which implicitly assumes antenna monopulse errors can correctly account for any off-axis measurements which might occur.

2.3.4 Radar Orientation

For the phased-array radar option, the boresight azimuth and elevation directions must also be specified. These give the direction of the normal to the phased-array face. In addition, the azimuth and elevation coverage limits must also be specified. There are no corresponding boresight direction or coverage limits input to ARIES for the RAE radar option, the ARIES program assumes only that an RAE radar requires a non-negative target elevation.

2.3.5 Other Radar Parameters

Other radar parameters which must be input are its RF frequency and its beamwidth. The radar frequency is used in scaling the ionospheric refraction tables and the ionospheric scintillation tables, while the beamwidth is required in the multipath calculations. See Reference 2 for these frequency and beamwidth adjustments to ionospheric and multipath effects.

2.4 Tracker Models

Under tracker model parameters would fall, for example, the values of α and β in an α-β filter, or the clamping levels and time constants of a working Kalman-type recursive filter. Presently, however, ARIES has only one type of "tracker" built into its code: the MLE tracker described in Section 7 of Reference 1. This MLE tracker puts a physical trajectory through the set of measurement data, with the trajectory determined completely (Reference 1, Section 4) by the ARIES Earth Model (Reference 1, Section 2). The only Tracker Model parameter currently required for the MLE tracker is the maximum number of iterations to be used in its trajectory-fitting process. For speed-of-execution reasons, the MLE starts with the true target state vector in its trajectory-fitting process, so that a few iterations generally provide good convergence (such initialization of the MLE algorithm does not effect its final solution but merely yields a great savings in computation time).

2.5 Discriminants

The ARIES program is designed to provide a testbed for discriminants written in the form of a discrimination subroutine which - having access to data bases stored in common arrays - would perform the discrimination function. At present the discrimination routine is merely a "dummy" routine which identifies each target in track as being a "threatening object" for purposes of handing over to an interceptor, and so discrimination parameter inputs are not currently required.

2.6 Interceptor Models

The ARIES program is also designed to enable inputting parameters associated with the given interceptor models. Midcourse-correction error residuals, drag and lift parameters, interceptor air frame response parameters, etc., would be typical of the interceptor model parameters envisioned as inputs to ARIES. Note that just as with the tracking models which are built into the program itself, the user only need input parameters to the interceptor models.

2.7 Simulation Scenario Controls

Simulation scenario control cards are divided into five areas:

Overall Scenario
Measurements Scenario
Tracking Scenario
Discrimination Scenario
Interception Scenario

2.7.1 Overall Scenario

The overall scenario contains the objectives of running the ARIES test, explaining in English why it is being run and giving a general overview of it. The only actual parameters that are input are the number of Monte Carlo runs that are desired, a "store-mode" switch and a seed number used in the random number generation so that the runs may either be repeated or made statistically independent from one ARIES Test Run to the next.

2.7.2 Measurements Scenario

The measurements scenario defines which radar noises and environmental effects are to be used in corrupting the radar measurements. Available options include the radar biases, jitter and thermal noises, tropospheric and ionospheric refraction, multipath, and ionospheric scintillation. In addition, the user inputs fractions of the refraction effects which one cannot account for through modeling: P_T is the input fraction of unremovable tropospheric refraction, P_I is the unremovable ionospheric refraction. For example, $P_T = .2$ means that ARIES will assume tropospheric refraction effects are sufficiently well understood that 80% of the effect can be accounted for and corrected, leaving only 20% of the tropospheric refraction uncorrected and thus corrupting the radar measurements. Similarly, $P_I = .4$ means that 60% of the ionospheric refraction can be correctly predicted and accounted for, leaving 40% uncorrected and corrupting the radar measurements. An analogous factor, P_M, is read into the program for unremovable multipath effects. Although in practice $P_M = 1$

has been used with the current ARIES multipath model, some future multipath model might permit use of P_M less than unity.

2.7.3 Tracking Scenario

The tracking scenario defines the tracks that are actually to be performed. While many different radars and targets may be input to the program, only specified targets will be tracked by specified radars over those intervals that are put into the tracking scenario. The number of track intervals, the beginning and ending parameters for each track interval (for example, start track at range 2000 Km track down to an altitude of 600 Km), must be input. In addition to such start- and stop-track information, the PRF must also be specified for each track interval.

2.7.4 Discrimination Scenario

While ARIES is designed to take a discrimination model, such a model has not yet been put into the program, and as yet the discrimination scenario has not been defined. The program will read parameters that are required by the discrimination scenario (e.g., the altitude or a time at which discrimination should begin, or which radar's data is to be used in discrimination, etc.).

2.7.5 Interception Scenario

The interception scenario has to define for each interceptor the state vectors which it is to use in obtaining the intercept points. It also defines the points at which the intercept correlation and covariance matrices, error ellipsoids, and error spheres are to be computed. This may be done from multiple handover state vectors, as explained in detail in Section 5.

2.8 Edit Controls

Each section of the ARIES Test Report (with the exception of Section 1) is subject to edit controls as specified by the user. These controls determine the types of printout to be used in the corresponding section and there are one set of controls for each section of the report. For example, in Section 3 the edit controls determine whether or not various environmental tables are to be printed out, while in Section 8, the edit controls determine whether or not a radar coverage summary is desired, which radars and targets nominal information and ground-plane plots are to be printed out, etc. There are several Section 8 printout options and these are also specified in the edit control cards. Under Section 9, the edit controls are used to call for RCS plots, the RCS output tape, etc. The details of the edit control cards are explained in Section 5.2.

***

SECTION 3--PROGRAM STRUCTURE

It is convenient for discussion to define three sections of the ARIES Program, divided into:

Pre-simulation Logic
Simulation Logic
Post-simulation Logic

Pre-simulation logic is concerned with interpretation of the user's request, and setting up tables and parameters preparatory to simulation. Simulation logic involves the simulated flight of the target, the radar's tracking it, etc. Post-simulation logic deals with gathering the statistics generated during the simulation into appropriate form for the ARIES Test Report.

3.1 Pre-Simulation Logic

The user-specified parameters are grouped according to the model being described, using a set of punched cards known as a "data packet", described below. Each type of "data packet" is read by a particular "reading" routine. The "reading" routines interpret the input parameters, perform coordinate transformations, etc., as necessary in order to fill COMMON data-storage arrays. After storing all input and computed data, the "reading" routines call upon "writing" subroutines to produce Sections 1-7 of the ARIES Test Report.

Section 8 of the ARIES Test Report contains pre-simulation nominal and radar coverage information requested by the user.

3.1.1 Data Packets

Input Data Cards are grouped into packets of the following types:

Scenario Packets
Edit Packets
Target Packets
Environment Packets
Radar Packets
Tracker Packets
Schema Packets
Interceptor Packets

These packets and the options available with each are each described in detail in Section 5. Here we merely want to explain the "data packet" in general terms.

The first card of each packet must have the format:

KEYWORD NUMBER NAME

The KEYWORD starts in Column 1, and only the first four letters of the KEYWORD are used by the program. NUMBER starts in Column 11 and may run from 00 to 99 (depending on which data packet is being specified). NAME starts in Column 21 and may be up to 16 Alphanumeric characters in length.

EXAMPLES:

Column 1	Column 11	Column 21
TARGET	02	RV TYPE 6
RADAR	10	TRADEX
SCHEMA	04	MULLIN SCHEMA

Following the KEYWORD card, each packet may contain up to 40 other cards. These are read in by free-format Subroutine FREAD.

FREAD performs two functions: it stores input cards in for subsequent printout in the ARIES Test Report, and it reads in an array of free-format numbers. Numbers are read in following a $ sign until a second $ sign is encountered.

The numbers found on the packet cards are stored in order. The required order for any particular type of packet is specified under the packet's description (see Section 5 for the individual packet descriptions). All information must be confined to columns 1 to 72, columns 73 to 80 are ignored.

NOTE: If the number of cards in a Packet exceeds 40 (not counting the KEYWORD card), this will cause the entire test run to abort. If the $ is not included on the last card, then the next data packet will be treated as part of the current packet, and garbage will result.

3.1.2 Reading Routines

Each input data packet is read by a specialized reading subroutine, called up by the MAIN ARIES Program in response to the KEYWORD appearing on the first card of the data packet. Each reading subroutine has a name composed of the packet's KEYWORD, with the suffix "IN" attached. Thus SCENario INput cards are read by Subroutine SCENIN, EDIT INput cards by EDITIN, etc.

To provide the user with the ability to make comments (explaining his purpose, his model, or whatever) replete with numerical quantities, ARIES reading routines ignore all information appearing before a $ sign. Having located the first $ sign in a data packet, the first task of each ARIES reading subroutine is to strip off all subsequent numerical quantities (ignoring all non-numerical characters) until a second $ sign occurs. This second $ sign signifies the end of the data packet, and ARIES assumes that the next input card will be the KEYWORD card of the next data packet.

After gathering all numerical quantities of interest from the data packet, the reading subroutines interpret the parameters according to which option number has been selected (Parameters and Options for each data packet are given in Section 5). In many cases this "interpretation" involves considerable calculations. For example, if the user specifies a target's metric information by choosing the "minimum-energy trajectory" option between specified launch and impact points, a great deal of iterative calculation must be performed (see Reference 1, Section 6) in order to arrive at the appropriate ECI state vector which the reading routine must store into the target's COMMON data file (these data storage files are described in the following Subsection, 3.1.3).

The third and final task of each of the ARIES reading subroutines - having (1) read the input cards, (2) interpreted them, and (3) stored the appropriate information into COMMON data files - is to (4) print out both the entire data packet (except for the KEYWORD card) and as much of the useful COMMON data file information as is requested by the user, in the appropriate section of the ARIES Test Report. The contents of these sections is described in detail in Section 4 of this report. The subroutines which write them are described below in Subsection 3.1.4.

3.1.3 Data Storage Files

There are eight COMMON data files associated directly with input pre-simulation data: controls, edit specifications, and model parameters. In addition to these files there are other files used by various subroutines during the "simulation" phase of an ARIES Test Run. Each of these latter files will be described in the appropriate subsections of Section 3.2, and the present section is only concerned with the eight pre-simulation COMMON data-storage files:

SCRIPT(I,K)
EDITS(I,15)
TARGET(I,J)
ENVIRO(I,K)
RADAR(I,N)
TRACKR(I,K)
SCHEMA(I,K)
INTERC(I,K)

The file SCRIPT(I,K) contains all input SCENARIO information with:

K = 1 for Measurements Scenario
K = 2 for Tracking Scenario
K = 3 for Discrimination Scenario
K = 4 for Interception Scenario
K = 5 for Overall Scenario

The MEASUREMENTS SCENario 01 data packet (see Section 5.1.2) is read by Subroutine SCENIN and the following information stored in the SCRIPT(I,1) data file:

I = 1	Radar Biases Switch (0 = no biases requested, 1 = biases requested)
2	Radar Range-Independent Random Noise (Jitter) Switch
3	Radar Range-Dependent Random Noise (Thermal) Switch
4	Tropospheric Refraction Switch
5	Unremovable Fraction of Tropospheric Refraction, P_T
6	Ionospheric Refraction Switch
7	Unremovable Fraction of Ionospheric Refraction, P_I
8	Multipath Switch
9	Unremovable Fraction of Multipath, P_M
10	Ionospheric Scintillation Switch
11-99	--- not used at present ---
100	Total count of numbers appearing in the SCENARIO 01 data packet

The TRACKING SCENario 02 data packet (see Section 5.1.3) is read by Subroutine SCENIN and the following information stored in the SCRIPT(I,2) data file:

I = 1	Number of the Radar which is to do the tracking
2	Number of the Target which is to be tracked
3	The number of track intervals to be used
4	Type of Parameter used to specify start of 1st track interval

I = 5 Parameter specifying start of 1st track interval

6 Type of Parameter used to specify end of 1st track interval

7 Parameter specifying end of 1st track interval

8 Radar PRF to be used during 1st track interval

9-13 Repeat quantities in 4-8 for the 2nd track interval (if there is to be one)

14-18 Repeat quantities in 4-8 for the 3rd track interval (if there is to be one)

· etc.

· Repeat quantities 1-18 for a different radar target combination

100 Total count of numbers appearing in the SCENARIO 02 data packet

For each radar/target combination up to 5 intervals and a maximum number of 174 track points total is allowed.

The DISCRIMINATION SCENario 03 data packet (see Section 5.1.4) is read by Subroutine SCENIN and the following information stored in the SCRIPT(I,3) data file:

I = 1 --- not used at present ---

2 --- not used at present ---

3 --- not used at present ---

·

·

·

100 Total count of numbers appearing in the SCENARIO 03 data packet

The INTERCEPTION SCENario 04 data packet (see Section 5.1.5) is read by Subroutine SCENIN and the following information stored in the SCRIPT(I,4) data file:

I = 1 Number of the Interceptor to be used

2 Number of state vectors to be handed to the interceptor

3 Type of Parameter used to specify which state vector is to be used

4 Parameter specifying which state vector is to be used

5 Type of Interceptor Operation to be performed

6 Operational Parameter 1

7 Operational Parameter 2

8-12 Repeat quantities 3-7 for the 2nd state vector (if any)

13-17 Repeat quantities 3-7 for the 3rd state vector (if any)

.

.

.

100 Total count of numbers appearing in the SCENARIO 04 data packet

The MISSION SCENario 05 data packet (see Section 5.1.1) is read by Subroutine SCENIN and the following information stored in the SCRIPT(I,5) data file:

I = 1 Number of Monte Carlo runs requested during ARIES Test Run.

2 Switch to either compute new measurements on each Monte Carlo run (=0), or to store the measurements on 1st Monte Carlo run for all subsequent Monte Carlo runs (=1).

3 Seed for ARIES random number generator

4-98 --- not used at present ---

99 Current value of random number generator

100 Seed for ARIES random number generator

The file EDITS(I,K) contains all input EDITS information, where K corresponds to the section of the ARIES Test Report to which the information applies.

NOTE: There are no Edit controls over Section 1 of the ARIES Test Report, thus "EDITS K" data packets are only meaningful for Sections 2 through 15. Of these, only Sections 3, 8 and 9 presently utilize the edit controls available in ARIES.

The EDITs 03 data packet (see Section 5.4.1) is read by Subroutine EDITIN and the following information stored in the EDITS(I,3) data file:

I = 1	ENVIRO data packet card-listing switch (0 = no list, 1 = list)
2	Environmental tables listing switch (tropospheric refraction, ionospheric refraction, multipath, ionospheric scintillation) (0 = no list, 1 = list tables to be used during ARIES Test Run, 2 = list all tables, whether to be used or not).

The EDITs 08 data packet (see Section 5.4.2) is read by Subroutine EDITIN and the following information stored in the EDITS(I,8) data file:

I = 1	Radar Coverage Summary Switch (1 = summary, 0 = no summary desired)
2	Number of radar for which nominal is desired
3	Number of target for which nominal is desired
4	Time interval on nominal printout
5	Type of printout desired
6-9	Repeat quantities in 2-5 for the 2nd nominal (if any)

I=10-13 Repeat quantities in 2-5 for the 3rd nominal (if any)

· etc.

· etc.

100 Total count of numbers appearing in the EDITS 08 data packet

The EDITs 09 data packet (see Section 5.4.3) is read by Subroutine EDITIN and the following information stored in the EDITS(I,9) data file:

I = 1 RCS Listing Control

2 RCS Magnetic Tape Output Control

3 RCS vs. Time Plot Control

4-99 --- not used at present ---

100 Total count of numbers appearing in the EDITS 09 data packet

For each location (EDITS(I,9)) a number N is picked up (0 is default) which generates the respective form of output for the first N Monte Carlo simulations. N=0 bypasses that form of output. Any output mixture of listing, tape, or plot is acceptable.

The file TARGET(I,J) contains all the input information on the TARGet J data packet (Section 5.5). This packet is read by Subroutine TARGIN, and after necessary computations, the following information stored in the TARGET(I,J) data file:

I = 1 Metric TAL time (Sec)

2-4 Position data in ECI with X-Axis thru Greenwich longitude at time of launch (M)

5-7 Rate data in ECI coordinates (M/Sec)

8-10 Acceleration data in ECI coordinates (M/SEC**2)

I = 11	Altitude (M)
12	Longitude (Radians)
13	Geodetic Latitude (Radians)
14	Drag table number
15	RCS TAL time
16-18	Orientation data (Euler Angles with respect to ECI coordinate of the principal body axes) (Radians)
19-21	Angle rate data (Radians/Sec)
22-24	Angle-Acceleration (Not Used)
25-27	Moments of Inertia (KG/M**2)
28	RCS Table Number
29	TAG Time of Launch Point (Sec)
30	Launch longitude (Radians)
31	Launch geodetic latitude (Radians)
32	Launch angle (Radians)
33	Reentry TAL (Sec)
34	Reentry longitude (Radians)
35	Reentry geodetic latitude (Radians)
36	Reentry angle (Radians)
37	Impact TAL (Sec)
38	Impact longitude (Radians)
39	Impact geodetic latitude (Radians)
40	Impact angle (Radians)
41-44	Target name (4A4)
45	Launch azimuth (Radians)

I = 46 SUM

47 TZ

48 HELP2

49 SK2

50 H

51 GA

52 SZ

53 BETA

54 ALPHA

55 FACT

56 P

(I = 46–56: Constants used in integration of the RCS State Vector ahead and backwards in time. For definitions, see Subroutine RCS and Reference 2, Section 7.)

57 RCS Sinusoid Option -- Peak RCS (dbsm)

58 -- Null RCS (dbsm)

59 -- Frequency (Radians/Sec)

60 RCS Cylinder Option -- Cylinder Radius (Meters)

61 -- Cylinder Length (Meters)

62 RCS Sphere Option ---- Cross-Section (dbsm)

63-71 W(3,3) Matrix rotates momentum frame into ECI coordinates

72-80 T(3,3) Matrix rotates body axes into ECI coordinates

81 RCS Initialization Switch

The file ENVIRO(I,K) contains all ENVIronment Model parameters, with

K = 1 for Tropospheric Refraction Model

K = 2 for Ionospheric Refraction Model

K = 3 for Multipath Model

K = 4 for Ionospheric Scintillation Model

The ENVIronment 01 data packet (see Section 5.6.1) is read by Subroutine ENVIIN and the following information stored in the ENVIRO(I,1) data file:

I = 1 Type of tropospheric refraction table to be used

2-10 (Reserved for future user-input tropospheric refraction model parameters)

11-100 Area for storage of tropospheric refraction tables to be used during ARIES Test Run.

The ENVIronment 02 data packet (see Section 5.6.2) is read by Subroutine ENVIIN. If the daytime ionospheric refraction tables are to be used, ENVIRO(I, 2) is set equal to unity, while if the nighttime ionospheric refraction tables are to be used, ENVIRO(I,3) is set equal to unity. The remaining ENVIronment 02 data packet parameters are copied into the corresponding (daytime or nighttime) array. Thus the ENVIRO(I,2) data file has:

I = 1 Flag (=1) if daytime iono refraction model is to be used

2-10 (Reserved for future input daytime ionospheric refraction model parameters)

11-100 Area for storage daytime ionospheric refraction tables to be used during ARIES Test Run

while ENVIRO(I,3) contains the analogous information for the nighttime ionospheric refraction model.

The ENVIronment 03 data packet (see Section 5.6.3) is read by Subroutine ENVIIN and the following information stored in the ENVIRO(I,4) data file:

I = 1	Type of multipath reflection coefficient table to be used
2	Type of multipath radar sidelobe level table to be used
3	Proportionality constant K used in angle-error equation
4-10	(Reserved for future multipath model user-input parameters)
11-100	Area for storage of multipath tables to be used during ARIES Test Run

The ENVIronment 04 data packet (see Section 5.6.4) is read by Subroutine ENVIIN and the following information stored in the ENVIRO(I,5) data file:

I = 1	Type of ionospheric scintillation model to be used
2-10	(Reserved for future iono scintillation model user-input parameters)
11-100	Area for storage of ionospheric scintillation tables to be used during ARIES Test Run

The file RADAR(I,N) contains all the input information on the RADAr N data packet (see Section 5.7), where N is the radar number assigned. This subroutine is read by Subroutine RADAIN, and after necessary computations, the following information stored in the RADAR(I,N) data file:

I = 1	Radar Type 0 = Dish Radar (RAE), 1 = Phased Array Radar (RUV)
2	Radar longitude (Radians)
3	Radar geodetic latitude (Radians)
4	Radar height above WGS-66 Ellipsoidal Earth Model (M)

I = 5 Sensitivity: reference range (M)

6 Angle-error slope parameter

7 Range bias (M)

8 Traverse bias (Radians or Sines)

9 Elevation bias (Radians or Sines)

10 Sigma of range-dependent range measurement noise (M)

11 Sigma of range-dependent traverse measurement noise (Rad. or Sin.)

12 Sigma of range-dependent elevation measurement noise (Rad. or Sin.)

13 Sigma of range-independent range measurement noise (M)

14 Sigma of range-independent traverse meas. noise (Rad. or Sin.)

15 Sigma of range-independent elevation meas. noise (Rad. or Sin.)

16 Tracking algorithm number

17 Pulse repetition frequency, PRF (HZ)

18 Phased-array radar: Azimuth direction of boresight (Radians)

19 Phased-array radar: Elevation direction of boresight (Radians)

20 Phased-array radar: Lower limit of azimuth coverage (Radians)

21 Phased-array radar: Upper limit of azimuth coverage (Radians)

22 Phased-array radar: Lower limit of elevation coverage (Radians)

23 Phased-array radar: Upper limit of elevation coverage (Radians)

24-32 Rotation matrix from ECF (Greenwich) to radar XYZ coordinates

33-35 Translation vector from ECF to radar coordinates (M)

36-39 Radar Name (4A4)

40 Radar Frequency

41 Radar Beamwidth (Radians)

I=42-44 Radar location in ECF XYZ coordinates (Meters)

45 Radar ID No.

The file TRACKR(I,K) stores user-input parameters supplied in the TRACker K data packet for the Kth tracking algorithm. At present ARIES incorporates only one "tracking" algorithm, the MLE estimator which has K=1 (see Reference 1, Section 7) and which requires only one user-input parameter (the number of iterations to be used in the trajectory-fitting process). The TRACKR(I,K) array is the area in which the user supplied time-constants, etc., of alternative trackers (such as a recursive Kalman filter or an α-β type of tracking algorithm) would be stored.

The file SCHEMA(I,K) is intended to store input parameters supplied by the user via the SCHEma K data packet for the Kth discrimination algorithm. Since at present ARIES has no discrimination algorithms, this array is intended for program "expansion".

The file INTERC(I,K) is intended to store user-input parameters for the Kth interceptor model. Since at present ARIES has no interceptor modeling, this array is intended for program "expansion".

3.1.4 Writing Routines

There are 15 writing routines of ARIES, each corresponding to one of the 15 sections of the ARIES Test Report described in Section 4. Thus Subroutine SECT01 writes everything found in the 1st section of the ATR, Subroutine SECT12 writes everything found in the 12th section, etc. In addition to writing their ATR sections, Subroutines SECT08 and SECT09 also generate plots.

Subroutine SECT08 plots the World Map and ground plane trace (see Section 4.10.3) for each trajectory for which a nominal is requested by the user.

Subroutine SECT09 plots the RCS information appearing in Section 9 of the ATR (see Section 4.11.5). This includes plots of effective RCS for principal and opposite polarizations, as well as plots of actual RCS for principal and opposite polarizations, and a plot of ionospheric scintillation.

3.1.5 Radar Coverage Routine

Subroutine CUVRGE is responsible for outputting Section 8 of the ARIES Test Report. When requested by the user, the nominal trajectory of a specified target - viewed by a specified radar - is printed out at time intervals specified by the user. There are four printout options available (see Section 5.4.2):

(1) RAE positions and rates, altitude, printed out approximately 30 seconds before target enters radar coverage, until target leaves radar coverage.

(2) Same as Option (1), but for RUV positions and rates.

(3) Same as Option (1), but for entire trajectory, launch to impact.

(4) Same as Option (2), but for entire trajectory, launch to impact.

In addition, if plots are requested by the user, Subroutine CUVRGE computes the target's ground-plane trajectory data required for the type of Earth/Trajectory plots shown on page 34 of the Appendix.

3.2 Simulation Logic

Once the user-input data packets have been interpreted (Sections 1-7 of the ARIES Test Report) and the nominal trajectories generated (Section 8 of the ATR), ARIES is ready to start the actual simulation. The simulation is all controlled by Subroutine MONITR, which using the various user-input scenario data, calls upon various other subroutines (MEASUR, TRACKS, DISCRM, and INTCPT) to generate the radar measurements, track the various targets, discriminate among the targets to identify threatening objects, and finally to perform the functions associated with the intercept of the threatening objects.

3.2.1 MONITR Subroutine

The Subroutine MONITR is intended to control and monitor the entire simulation phase of an ARIES Test Run, doing so through use of the five input scenarios:

Overall Scenario
Measurements Scenario
Tracking Scenario
Discrimination Scenario
Interception Scenario

These user-specified scenarios were described in Section 2.7. The parameters in them are available to the MONITR Subroutine via the COMMON data array SCRIPT(I,K), as explained in Section 3.1.3.

The MONITR conducts a Monte Carlo run using principally the Tracking Scenario. For each radar/target combination called for in the track scenario, MONITR sequences through all the requested track intervals, generating radar measurements at the specified PRF through calls to Subroutine MEASUR.

The measurements and their variances are stored in the COMMON data array MEAS(I,J,N), and are thus available to the TRACKS subroutine which determines an estimate of the target's state vector to be handed over to the interceptor Subroutine INTCPT. The measurements are also available to the discrimination Subroutine DISCRM, and the state vectors of those targets labelled by Subroutine DISCRM as being "threatening" are considered by Subroutine INTCPT.

3.2.2 Radar Measurements Subroutine

If one had to pinpoint the heart of the ARIES Test Program, it would have to be in the Subroutine MEASUR. That subroutine utilizes the various environmental models (refraction, multipath, scintillation) and accounts for radar measurement errors (thermal and jitter noises, and biases), coming up with either a corrupt RAE or RUV measurement (depending on the type of radar specified by the user) stored in the MEAS(I,J,N) array. Also stored in that array is the time of the measurement and its variances in the three position coordinates. These variances are used by the TRACKR to weight in each measurement in its trajectory-estimation process, and might also prove useful to future discrimination schemes. Reference 2 gives a complete discussion of the generation of the radar measurements in ARIES.

3.2.3 Radar Tracking Subroutine

Theoretically Subroutine TRACKR is to perform the trajectory estimate updating after each measurement. This would be the case, for example, if Tracking Option 2 (recursive Kalman filter) were fully implemented in ARIES and requested by the user. When the (nonrecursive) Maximum Likelihood Estimator Option 1 (which is currently implemented in ARIES) is selected by the user, the TRACKS Subroutine calls upon Subroutine MAXLIK. MAXLIK stores the measurement points until the end of a track interval. If a handover state vector is requested for the end of that track interval, the MAXLIK performs its trajectory-fitting job, as explained in detail in Section 7 of Reference 1.

3.2.4 Discrimination Subroutine

The discrimination Subroutine DISCRM is intended to select threatening targets from among all the targets in track, using all data made available on each target from all radars (which radars track which targets is determined by the tracking scenario). In general several different discrimination algorithms might be included in DISCRM, and the user-input discrimination SCENario 03 data packet would select one of the algorithms. The parameters associated with each discrimination schema are input via the SCHEma data packet (see Section 5.7). Since at present ARIES has no actual discrimination algorithm, Subroutine DISCRM simply labels all tracked targets as "threatening". This is done via the COMMON data file DECISN. This data file would in general contain all information to be handed over to the interceptor Subroutine INTCPT, such as which radar's state vector estimate is to be used, the degree of confidence in the target identification, etc.

3.2.5 Interceptor Subroutine

The INTCPT Subroutine is intended to perform all the calculations required for intercept (e.g., extrapolation ahead in time of the handover state vector and its covariances), the actual fly-out data on the interceptor, modeling of midcourse and terminal guidance errors, etc. Uncertainties in the target's position, miss distance calculations, etc., fall within the province of this subroutine.

The modeling of interceptors has been left as an expansion item for ARIES (Reference 3). At present, the Subroutine INTCPT is limited to a role of taking handover state vectors and their associated correlation and covariance matrices and extrapolating them ahead to a series of potential user-specified intercept points. At each such point the correlation and covariance matrices are diagonalized to yield an "ellipsoid of uncertainty" in the handover target's position. Finally an "equivalent sphere of uncertainty" is determined...i.e., that distance or radius from the extrapolated handover state vector within which the target falls, to within a probability 0.99 under the assumption that the error ellipsoid has uncorrelated normal random variables in its three principal axes directions. It is this "error sphere radius" which has proved most useful in the ARIES studies to date (Reference 3).

CAUTION: For mathematical reasons, the computation of correlation matrices requires a minimum of 3 Monte Carlo runs, while the computation of covariance matrices requires a minimum of 4 Monte Carlo runs.

3.3 Post-Simulation Logic

Subroutine OUTPUT accomplishes the job of producing a logically-organized ARIES Test Report. During execution Sections 1 through 7 are output immediately after input. For example, Section 1 is written out before the input cards for Section 2 are read. Each section is written by a separate subroutine: SECT01 writes out all of Section 1, SECT02 writes out all of Section 2, etc. These sections are written to the print file, logical file KOUT, and KOUT is set to 6 (Tape6) in Subroutine INITAL. KOUT is passed to all subroutines in the labeled common REPORT.

The two Subroutines TOP and BOTTOM print a header containing the title of the run and a bottom line containing the section number, date, time, and page number on each page.

Each section of the ARIES Test Report writes a table of contents line to a logical file called KTOC. KTOC is set to 20 (Tape20) by Subroutine INITAL. Subroutine OUTPUT processes KTOC and produces a table of contents at the end of the run.

Section 8 and the sections called in the "real-time" loop (Sections 9 through 12) write to separate logical files. Section 8 uses its file as temporary storage to permit the writing of a summary report as well as the complete report of the Section 8 results. The files generated by the sections in the real-time loop are read by OUTPUT and written to KOUT in proper order and with proper pagination.

In the "real-time" sections, lines needed for the table of contents are written without page numbers but with a TOC flag in column 2. OUTPUT assigns the appropriate page number to each flagged TOC line and puts it out to KTOC. OUTPUT's last job is to rewind KTOC and write it out as a table of contents.

The following files are used by the output routines and must be specified on the ARIES program card:

File Name	Variable Name	Purpose
Tape6	KOUT (global)	Printer output.
Tape8	KWR (local)	Temporary file for Section 8.
Tape9	KWR (local)	Temporary file for Section 9.
Tape10	KWR (local)	Temporary file for Section 10.
Tape11	KWR (local)	Temporary file for Section 11.
Tape12	KWR (local)	Temporary file for Section 12.
Tape20	KTOC (global)	Temporary file for table of contents.

The variable KWR is declared in labeled common REPORT, but is set locally by each section that uses it. Thus Section 8 sets it to 8 (Tape8), Section 9 sets it to 9 (Tape9), etc. The routines TOP and BOTTOM write to the locally set KWR. This causes top and bottom lines to be written to the temporary files for the files being multiplexed in the real-time loop (Sections 9 through 12). The sequential sections, 1 through 8, set KWR to KOUT before calling TOP and BOTTOM so that heading and trailing lines are written directly to the printer.

While Section 8 is one of the sequential sections, it must output a summary report, a figure page for the ground plane trajectory, and a full listing of the pre-mission nominals. These are treated as separate cases by SECT08. The call to SECT08 includes a flag called IPASS which indicates which of the three outputs to produce. When IPASS is 1, SECT08 writes the nominals to the temporary file KWR, when IPASS is 2, it writes a figure page for the ground plane trajectory plot, and when IPASS is 3, it produces the summary page and the full listing of the nominals.

The summary lines are the nominals at the start and end of coverage for each radar/target pair. These are flagged by SECT08 when IPASS is 1. When IPASS is 3, it rewinds KWR and prints out each flagged line. The flags are 'E' (enter), 'L' (leave), and 'S' (start) in column 2. Column 1 is blank. The start flag (S) indicates a new radar/target pair.

Sections 9 through 12 write lines to KWR appropriately set to its section number (NSECT). Each section keeps its own count of the lines written to its temporary file in a local variable called MLINE and when this count reaches the maximum line count for a page (LINEMAX), the section calls BOTTOM with the global variable NLINE set equal to MLINE. BOTTOM flags the bottom line with a 'B' in column 2. Column 1 is left blank. This flag is checked by OUTPUT to determine the page ending when the final output is produced.

As with all other sections, the multiplexed sections write out a title page and a table of contents line when first entered. The table of contents line is flagged with a 'T' in column 2.

Subroutine TOP ejects a page and writes a heading. TOP writes all lines to file KWR. This may be a temporary file or a printer output file.

To write to the printer the calling program must set KWR to KOUT before calling TOP. TOP should only be called by the output routines. Indiscriminate calls by other programs may cause unpredictable alignment of written lines, especially in Sections 8 through 12.

BOTTOM uses NLINE and the maximum line count, LINEMAX, to determine the end of the page. BOTTOM writes blank lines until the line count reaches the maximum count (currently 53), then writes a bottom line.

BOTTOM writes all lines to KWR. If KWR equals KOUT the lines go out to the printer, otherwise to the logical file designated by KWR. If writing is to go to KOUT, BOTTOM writes a page number as part of the bottom line, otherwise it omits the page number and flags the line with a 'B' in column 2. OUTPUT inserts the appropriate page number for this case.

The page counter, NPAGE, is incremented by BOTTOM whenever the page number is included in the output line.

The flags used by the output routines are listed below:

Flag	Set by	Purpose
B	BOTTOM	Mark bottom line for Sections 8 through 12
E	SECT08	Mark coverage entry for Section 8 summary
L	SECT08	Mark coverage exit for Section 8 summary
S	SECT08	Mark the start of new radar/target pair for Section 8 summary
T	(all)	Mark table of contents line.

All flags are set in column 2. Column 1 is left blank.

At the completion of the real-time loop, control passes to OUTPUT. OUTPUT calls OUTFIL with a section number to write the Sections 9-12. OUTFIL rewinds the temporary file and writes each line to the printer.

***

SECTION 4--ARIES TEST REPORTS

The primary output from an ARIES Test Run is an ARIES Test Report, portions of which may, at the user's option, be output on tape for subsequent processing by other programs.

In reading through the following descriptions of the contents of the various sections of the ARIES Test Report, the sample ARIES Test Report appearing in the Appendix should be continuously consulted by the reader.

4.1 Overall Format

The ARIES Test Report is intended to provide a complete and organized report on the inputs, operation and outputs of an ARIES Test Run. Following a Title Page and Table of Contents, there are potentially 13 Sections to the report, each covering a separate aspect of the simulation:

SECTION 1 -- MISSION SCENARIO, OBJECTIVES, AND CONTROL PARAMETERS

SECTION 2 -- TARGET MODEL DESCRIPTIONS AND PARAMETERS

SECTION 3 -- ENVIRONMENTAL MODEL DESCRIPTIONS AND PARAMETERS

SECTION 4 -- RADAR MODEL DESCRIPTIONS AND PARAMETERS

SECTION 5 -- TRACKING ALGORITHM DESCRIPTIONS AND PARAMETERS

SECTION 6 -- DISCRIMINATION SCHEMA DESCRIPTIONS AND PARAMETERS

SECTION 7 -- INTERCEPTOR MODEL DESCRIPTIONS AND PARAMETERS

SECTION 8 -- RADAR COVERAGE REPORT AND PRE-MISSION NOMINALS

SECTION 9 -- MEASUREMENTS QUALITY REPORT

SECTION 10-- TRACKING PERFORMANCE REPORT

SECTION 11 -- DISCRIMINATION PERFORMANCE REPORT

SECTION 12 -- INTERCEPTOR PERFORMANCE REPORT

SECTION 13 -- TEST MONITOR REPORT AND TEST EVENTS SUMMARY

These sections are "potential" inasmuch as they will only appear as required. For example, due to the absence of a discrimination schema at present in ARIES, Section 11 does not appear in the example of the Appendix.

Each section of the ARIES Test Report has been formatted to fit the 8½ x 11 format of the most technical reports. This limits the number of columns available to about 76 (there are 85 characters across each page, but approximately 9 columns are used as margins), a limitation which has not proved restrictive to date.

At the top of each page appears the contents of the 72-column alphanumeric Title Card supplied by the user as the first data card in the ARIES Test Run deck. At the bottom of each page appears the Section number, the date, the time-of-day at which the run began, and a page number.

4.2 Table of Contents

The titles appearing at the beginning of each section of the ARIES Test Report also appear on the Table of Contents, along with their corresponding page numbers. As can be observed from the example of the Appendix, not all 13 sections are included in the report nor the Table of Contents.

4.3 Mission Scenario, Objectives, and Control Parameters

Section 1 of the ARIES Test Report is the only section not under the EDIT controls which the user can exercise over Sections 2-13. This Section 1 is intended to introduce the SCENario data packets to give the "overall picture" to the reader of the goals and objectives being sought by the user on this ARIES Test Run. Reading through the examples of the Appendix, one finds that the objectives are frequently spelled out in the Comments area of each packet, followed by the control parameter information. This order is not necessary, however, as any desired non-numeric information/explanation may also be included within the data field of each ARIES data packet.

4.4 Target Model Descriptions and Parameters

Section 2 of the ARIES Test Report provides a record of each target model the user has supplied. For each target the input data packet appears, followed by a printout of some of the target's TARGET file data in the form to be used by ARIES. The input state vector (or the launch point state vector, for the three launch/impact options explained in Section 5.3) is given in an ECI coordinate frame, along with the altitude, longitude, and geodetic latitude of the initial state vector points. A Drag Table Number is an expansion item, if reentry studies become of interest.

Next follows the TARGET file data related to the computation of the target's radar cross-section (RCS). The input Euler angles which define the orientation of the principal body axes with respect to the inertial momentum frame (determined by the target's spin rates - see Reference 2, Section 7.2.2) are given, along with the input "spin" or "tumble" rates of the target about its principal body axes, the target's moments of inertia with respect to its principal body axes, and finally the RCS Table Number to be used in looking up its RCS given its aspect and roll angles as viewed by a radar (see Sections 7.4 and 7.5 of Reference 2).

Next in the TARGET FILE printout are given the "tag time" of launch. This "tag time" corresponds to the same reference time input by the user with his metric state vector information (the user might use Coordinated Universal Time, or local Time-of-Day, etc.). This choice of a "tag time" reference is arbitrary. ARIES works exclusively in Time-After-Liftoff, or simply TAL, of Target Number 1, but in order that the user may relate the TAL times appearing throughout the ARIES Test Report to his own choice "tag time", the "tag time" of launch appears here. In certain ARIES Test Report Sections - such as Section 8 described further below - both TAL and TAG time appear on the print-outs for the convenience of the user. For launch/impact options, TAG time and TAL are assumed identical in ARIES.

Launch, Reentry and Impact information appears next. In addition to the longitude and geodetic latitudes of each of these points, the elevation angle of the target is given, and in the case of the launch point, the launch azimuth as well.

As seen by the examples of TARGET FILES 2, 3, and 4 the special RCS option cases of a sphere, cylinder, and sinusoid each list the appropriate RCS parameters along with the other target file information.

4.5 Environmental Model Descriptions and Parameters

Section 5 of the ARIES Test Report contains printouts of all of the ENVIronment data packets submitted by the user. It also provides - at the user's option, as explained in Section 5.2.1 - for printouts of all the environmental tables available in ARIES, whether or not they are being used on the particular ARIES Test Run. In the following subsections we discuss only the tables associated with the various models, as they appear in an ARIES Test Report. The Environmental Models themselves are discussed briefly in Section 2.2 of this report, and in greater detail in Sections 4 to 6 of Reference 2.

4.5.1 Tropospheric Refraction Tables

The perturbations in the range and elevation measurements of a target's position by a radar are functions of the target's elevation and altitude. On page 14 of the Appendix there are two sets of tables. The upper tables give ΔR and ΔE as functions of elevation. The lower tables are entered with the target's altitude to yield two factors, FACTOR 1 and FACTOR 2, by which the ΔR and ΔE are weighted respectively. For details of how these tables were arrived at, see Reference 2, Section 4.1.

4.5.2 Ionospheric Refraction Tables

There are currently two sets of ionospheric refraction tables, as shown in the ARIES Test Report of the Appendix, pages 16 and 17. The first of these tables is for the daytime model, the second is for the nighttime model. As with the tropospheric refraction tables discussed in Section 4.5.1, these ionospheric refraction tables are seen to be functions of both the target's altitude and its elevation as viewed from a radar. Detailed discussion of how the tables were obtained can be found in Sections 4.1 of Reference 2.

4.5.3 Multipath Tables

Associated with the current ARIES two-path multipath model are two tables, one to obtain a reflection coefficient, the other a sidelobe level. These are two factors used in the calculations of the elevation error due to multipath interference. For details of the ARIES Multipath Model and sidelobe levels used, see Section 6 of Reference 2. The reflection coefficient table appears on page 19 of the Appendix.

4.6 Radar Model Descriptions and Parameters

Section 4 of the ARIES Test Report provides a record of each radar model the user has supplied. For each radar the input data packet is printed out, followed by a printout of some of the radar's RADAR file data, in the form it is to be used by ARIES, as shown on pages 21 and 22 of the Appendix.

The type of radar (RAE dish or RUV phased-array) is printed out, followed by the radar's location on the WGS-66 ellipsoidal earth model described in Section 2 of Reference 1. Next appears its sensitivity parameter, defined to be that range at which a 1 square meter target (0 dbsm) exhibits a 0 db signal-to-noise ratio on a single-pulse radar return. The angle-error slope parameter is used in the multipath model, described in Section 6 of Reference 2.

Next appear the radar bias numbers. If radar biases flag in the Measurements SCENario 01 data packet is set equal to 1, then these bias number magnitudes are treated as the standard deviations of three independent, zero-mean, normal distributions. For each Monte Carlo run a new set of biases is chosen randomly from these distributions. These biases are held constant over the entire Monte Carlo run. If the radar biases flag is set equal to 2, these biases are used directly and are held fixed over all Monte Carlo runs. When the flag is set equal to 0, the radar is treated as having no biases.

Range-dependent noise standard deviations are the next items appearing in the Radar File printout. These reflect the thermal-noise measurement-error sigmas corresponding to a signal-to-noise ratio of unity. For other values of SNR, these sigmas are inversely proportional to the square root of SNR. For a detailed discussion of how the SNR itself is arrived at taking into account both environmental effects and target tumbling, see Section 3.2 of Reference 2.

Range-independent noise standard deviations, representing jitter and quantization in the measurements, appear next, followed by the radar's frequency, beamwidth, and tracking algorithm number. The next item, the radar's maximum PRF, is not currently used in ARIES. It was included so that if in the future an adaptive discrimination algorithm were to request measurements for discrimination purposes (currently all measurements are generated only at the request of the tracking scenario), then the radar's maximum PRF might prove a limitation.

For a phased-array radar only, the azimuth and elevation directions of the array normal are given, together with the phased-array azimuth and elevation coverage limits.

Finally, for all radars, the rotation/translation matrices to transform between the radar's XYZ coordinates and ECF coordinates are given (these coordinate systems and the transformations between them are discussed in Section 5.2 of Reference 1).

4.7 Tracking Algorithm Descriptions and Parameters

Section 5 of the ARIES Test Report describes briefly the tracking algorithms available in the ARIES program, and also those algorithm parameters supplied by the user via the TRACker input data packets.

4.8 Discrimination Schema Descriptions and Parameters

Section 6 of the ARIES Test Report is intended to describe briefly the discrimination schema available in the ARIES program, along with those schema parameters supplied by the user via the SCHEma input data packets.

4.9 Interceptor Model Descriptions and Parameters

Section 7 of the ARIES Test Report is intended to describe briefly the interceptor models available in the ARIES program, together with those interceptor model parameters supplied by the user via the INTErcept input data packet.

4.10 Radar Coverage

Section 8 of the ARIES Test Report provides the trajectory information for each target/radar combination requested by the user via the EDITs 08 input data packet. Included in this section are:

Coverage Summary Table
Pre-mission Nominals
Earth/Trajectory Plots

4.10.1 Coverage Summary Table

On page 30 of the Appendix is an example of the Radar Coverage Summary Table. For each radar/target combination requested there are two lines of metric information printed out, the first line corresponding approximately to the time the target enters radar coverage and the second line corresponding approximately to the time the target leaves radar coverage. For each radar/target combination, the values printed out may be either TAL, R, A, E, Altitude, and Tag Time or else TAL, R, U, V, Altitude, and Tag Time, as specified by the user via the EDITs 08 data packet.

4.10.2 Pre-Mission Nominals

Page 31 of the Appendix gives ideal radar measurements on a target's positions, rates, and altitude, at a printout rate (actually a time interval) specified by the user. Such a printout is requested by the user via the EDITs 08 input data packet for any radar/target combination, and may be either over the time interval of the target's entire trajectory, or only over the time interval for which the target falls within the radar's coverage, a user option (see Section 5.2.2).

4.10.3 Earth/Trajectory Plots

For each radar/target combination for which the user requests a Nominal trajectory (see preceding subsection), a plot of the earth and the ground-plane projection of the target's trajectory are given, as seen in the example on page 34 of the Appendix. Note that even though the printout of the Nominal trajectory itself may only be requested during that time the target lies within radar coverage, the Earth/Trajectory plots always cover launch to impact.

Note: The view of the earth as shown is centered at a fixed longitude and latitude at present in ARIES, since the continental U.S.A. contains the impact points of greatest interest. The routines in ARIES, however, are more general, and as a very simple future modification to ARIES, the viewing longitude and latitude may be easily changed, by simply including them in the EDITs 08 input data packet. Also readily available - but not currently drawn - are grid lines of longitude and latitude for this Earth/Trajectory plot. The request for such lines and the parameters specifying their spacings would also be a useful and easy EDITs 08 data packet extension, since the subroutines for generating the lines have already been incorporated into the ARIES Program.

4.11 Measurements Quality Report

Section 9 is the first of four "real-time" sections, i.e., those generated during the actual simulation phase of an ARIES Test Run (as opposed to Sections 1-8 which were all related to "pre-simulation" inputs, etc.). In Section 9 are intended to be found those statistics related to measurement errors, as well as RCS information. Section 9 printout is all optional, being under control of the user via the EDITs 09 input data packet.

4.11.1 Measurement Error Statistics

At present ARIES yields no statistics relating to the measurement errors. Such quantities as average and rms biases due to tropospheric and ionospheric refraction, average and rms amplitude scintillation, average radar biases, etc., would prove most useful to anyone attempting to break the overall measurement error effects down into their individual components to determine their relative significance. Such a printout is perhaps one of the most useful expansion items for ARIES, and would be controlled via the EDITs 09 input data packet.

4.11.2 RCS Data

Currently available in Section 9 of the ARIES Test Report is a printout of TAL, effective RCS (both principal and opposite polarizations), and signal-to-noise ratio. When requested by the user via the EDITs 09 input data packet, this information is printed out on as many Monte

Carlo runs of each track as requested by the user. The true RCS is obtained through table-look-ups based upon the target's aspect and roll angles as viewed from the radar - see Section 7 of Reference 2 - while the effective RCS takes into account not only the true RCS but also the perturbations caused by ionospheric scintillation, measurement noises, etc. These latter calculations are also described in Reference 2.

4.11.3 Tape Option and Formats

In addition to the RCS data printouts in the ARIES Test Report itself (described in the preceding subsection), the user may also generate a tape of RCS-related information. The tape has the ARIES Test Run title, the date, time-of-day, the number of Monte Carlo runs included on the tape, the number of segments (start and stop times over which the measurements are taken), and the number of data records. Each data record contains:

Time (TAL seconds)
Target Number
Radar Number
Aspect Angle (radians)
Roll Angle (radians)
Polarization Angle
RCS-effective (PP and OP) (dbsm)
RCS-true (PP and OP) (dbsm)
Range
Range-rate
ECI radar position
ECI target position
T matrix

For a definition of the T matrix, see Section 7 of Reference 2.

4.12 Tracking Performance Report

Section 10 of the ARIES Test Report gives statistics and information related to the tracking algorithms' performance during the simulation phase of an ARIES Test Run. At present as seen on pages 36, 37 of the Appendix, only the mean square tracking error residuals appear in Section 10 (these are obtained by averaging over all measurement points of all Monte Carlo runs). There may be other track-related statistics desired in the future. If so, Section 10 is where they should appear, and the EDITs 10 input data packet can provide the corresponding user request flags and options.

4.13 Discrimination Performance Report

Section 11 of the ARIES Test Report is intended to provide the user with statistics related to the discrimination schema. Since at present the ARIES Test Program has but a trivial discrimination algorithm (if any target is in track by any radar it is considered threatening), then at present all that appears in Section 11 (pages 38, 39 of the Appendix) is a listing of all targets in track.

In the future, when and if a discrimination schema is incorporated into ARIES, then such information as the number of measurements made on each target, the resultant values of the various "features" used to distinguish threatening objects, etc., should prove valuable to the user interested in the performance of a discrimination schema. The user may employ the EDITs 11 input data packet to pass flags and parameters to Subroutine SECT11, thus controlling the types of discrimination schema performance data printed out.

4.14 Interceptor Performance Report

Section 12 of the ARIES Test Report is intended to provide a user with a comprehensive collection of all data pertinent to interception. The flight parameters of the interceptor and the miss distance are of prime interest. At present ARIES has no interceptor model, and thus it implicitly assumes a perfect interceptor. The miss-distance then becomes solely the error in estimating the target position - i.e., the error in the handover state vector after its extrapolation to the intercept point.

4.14.1 Miss Distance Correlation Matrices

As explained in Section 7 of Reference 1, the measurements made by a radar on a target during an ARIES Test Run are input to a tracker which provides a state vector estimate of the target's ECI positions and rates at the end of the tracking interval. On each Monte Carlo run this state vector is integrated ahead by Subroutine INTCPT to handover points of interest, and the 6-component error (column) vector between the estimated and true target positions and rates is computed. This error vector is post-multiplied by its transpose to yield an estimate of the handover "correlation" matrix. This matrix is averaged with other such estimated correlation matrices over all Monte Carlo runs in ARIES, thus obtaining the final estimated correlation matrix. This matrix is symmetric, so only the lower half of it is printed out in Section 11 of the ARIES Test Report at each handover point, as seen, for example, on page 41 of the Appendix.

4.14.2 Miss Distance Error Ellipsoid

Also found on page 41 of the Appendix are quantities labeled E1, E2, and E3. These are the eigenvalues obtained by diagonalization of the correlation matrix, as described in Section 8.4 of Reference 1. The diagonalization serves to transform the original (ECI-XYZ) coordinate errors into another orthogonal coordinates frame where the errors are uncorrelated. E1 is then the mean square error in the other two coordinates. The error uncertainty volume in this "uncorrelated-errors" frame thus becomes an ellipsoid with semi-axes of length $\sqrt{E1}$, $\sqrt{E2}$, and $\sqrt{E3}$.

4.14.3 Miss Distance Error Sphere

The orientation of the error ellipsoid discussed in the preceding subsection is available (although not presently printed out in the ARIES Test Report), but of little value to the user in attempting to obtain a mental picture of the handover state vector's position uncertainty. Far easier to visualize than ellipsoidal uncertainty volume is a spherical uncertainty volume, which requires but a single dimensional parameter (a radius) and no orientation parameters.

Thus, also to be found on page 41 of the Appendix is a quantity labeled "EQUIVALENT SPHERE RADIUS". The computation of this radius is described in Section 8.5 of Reference 1. Appearing directly under this EQUIVALENT

SPHERE RADIUS in the ARIES Test Report is found the PROBABILITY that the target lies with that radius of the handover state vector extrapolated to the intercept point of interest.

4.14.4 Miss Distance Covariance Matrices

Following the Correlation Matrices, Ellipsoidal and Spherical uncertainty numbers described in the preceding three subsections are found corresponding values related to the handover state vector covariance matrices. The Correlation matrices are generally useful for either a perfect interceptor or one being guided by an unbiased radar which corrects exactly for refraction perturbations to its measurements, etc. One can easily visualize a scenario, however, wherein both the target and interceptor are in track by the same biases (phased-array) radar, where the biased measurements of the target and interceptor positions would cancel one another when intercept computations were being made. In such a situation covariance matrices - which eliminate the mean error, as explained in Section 8.3 of Reference 1 - offer a more meaningful measure of target position uncertainty, at least as far as miss-distances are concerned. As with Correlation matrices, the Covariance matrix at each handover point of interest is symmetric, and thus only the lower halves of the Covariance Matrices are printed out on page 41 of the Appendix. Also shown there are the E1, E2, E3, and EQUIVALENT SPHERE RADIUS associated with the Covariance Matrix, which are defined and computed as explained in subsections 4.14.2 and 4.14.3, respectively.

4.15 Test Monitor Report and Test Events Summary

Section 13 of the ARIES Test Report is intended to present those statistics on the overall simulation which were gathered by Subroutine MONITR. While the present MONITR is somewhat simplistic and devotes no time to bookkeeping, one could conceive of it keeping track of both program statistics (i.e., how much time is spent in ARIES on the mathematics associated with the dynamics of a tumbling target, or with the tracking function, etc.) and simulation statistics (i.e., how many measurements were required before the DISCRM Subroutine came up with a decision, etc.). All such informative simulation statistics which seem inappropriate for inclusion in Sections 9 through 12 are envisioned as falling into the MONITOR Report of Section 13 of the ARIES Test Report.

In addition to the MONITOR Report, Section 13 is envisioned to ultimately give a TEST EVENTS SUMMARY such as the example given in Section 3.3.2 of this Technical Note.

***

SECTION 5--RUNNING THE PROGRAM

The ARIES input deck has the following components:

TITLE CARD
SCENARIO CARDS
EDIT CARDS
TARGET CARDS
ENVIRONMENT CARDS
RADAR CARDS
TRACKER CARDS
SCHEMA CARDS
INTERCEPTOR CARDS
END CARD

DATA PACKETS

The TITLE CARD is read in an 18A4 format (72 columns). This TITLE CARD will appear on the Title Page of the ARIES Test Report, as well as at the top of each page of the report. It is not necessary to include the date of the mission test run, since this appears automatically on each page of the report.

The END CARD must have "END " in Columns 1 to 4. When this card is reached in the input deck, no further input cards are read, and the mission test itself begins execution.

All other cards of the input deck are grouped in PACKETS, as explained in Section 3.1.1.

Each ARIES data packet allows for up to 40 cards of data. These cards are read in order, and a scan is performed on each successive card until a $ sign is encountered. The ARIES Program ignores all alphanumeric information appearing prior to the first $ sign in the data packet. After the first $

sign in the data packet is reached, ARIES strips off and stores each numerical quantity into an array as a floating-point quantity. This array is then made available to the appropriate reading subroutine (explained in Subsection 3.1.2), which in turn fills up the COMMON data-storage files (explained in Subsection 3.1.3).

In the following subsections we present detailed explanations of the options available with each type of data packet.

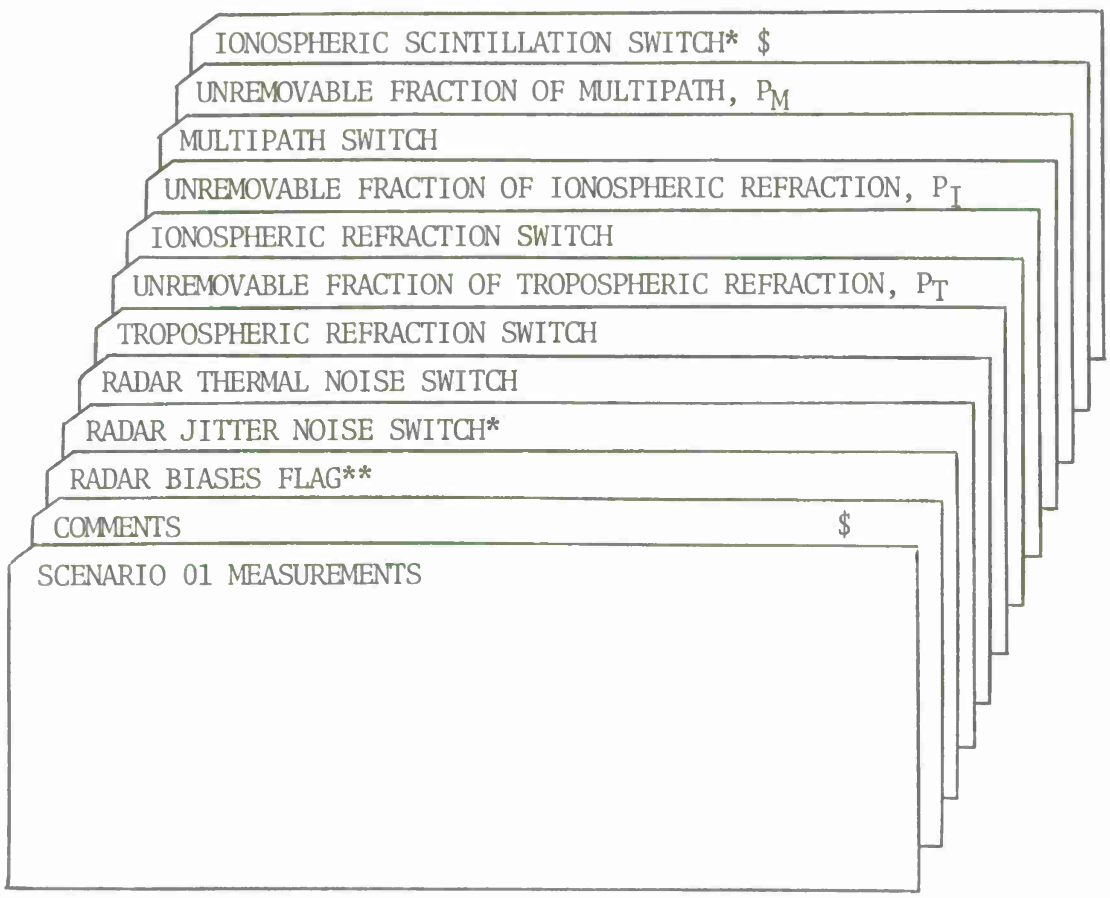
5.1 Program Control Packets

There are five types of packets which control the various aspects of the mission, as follows:

Measurements Scenario Packet
Tracking Scenario Packet
Discrimination Scenario Packet
Interception Scenario Packet
Mission Scenario Packet

Examples of these packets appear on pages 2 to 6 of the Appendix.

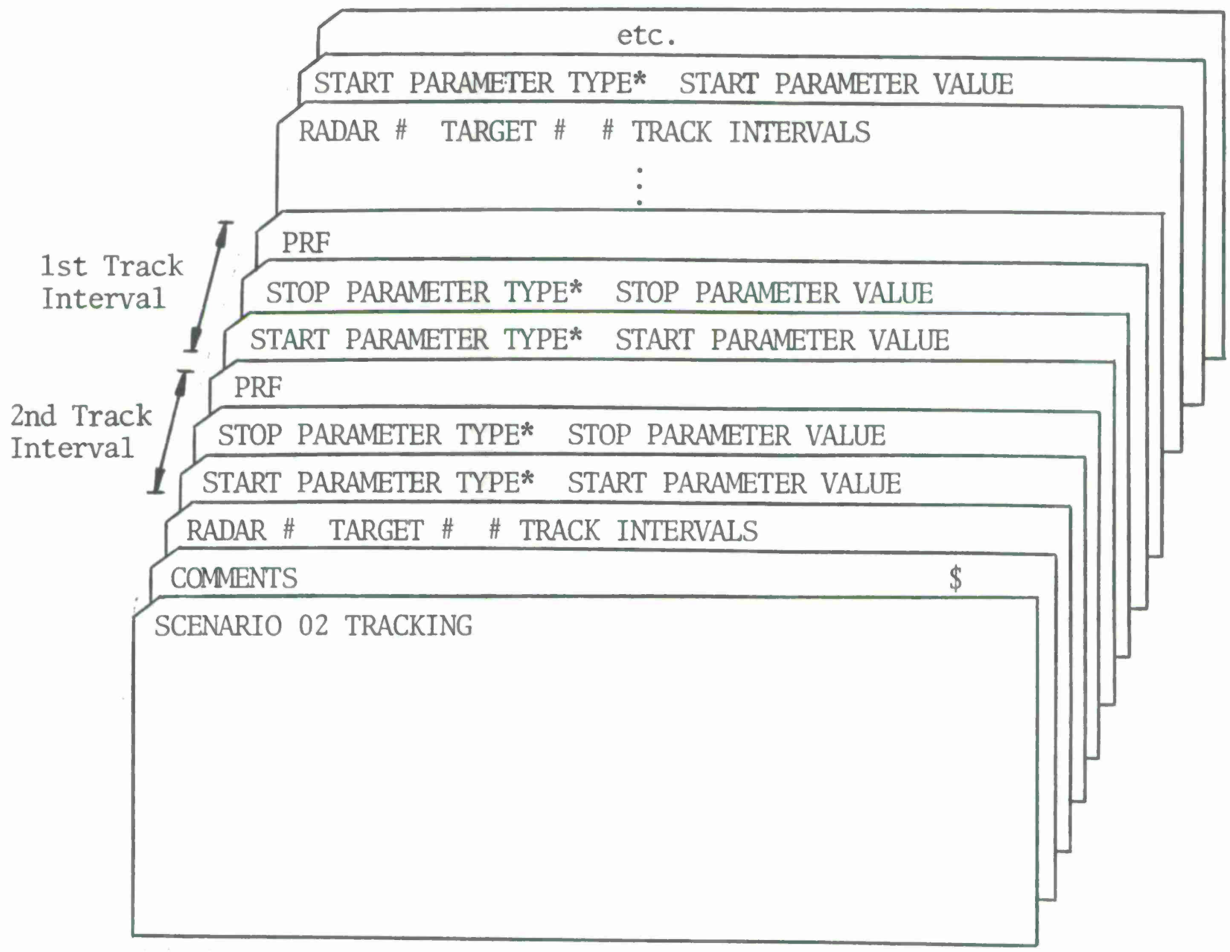
5.1.1 Measurements Scenario Packet



*For all switches, 0 means off, 1 means on

**0 = no biases, 1 = random biases, 2 = constant biases

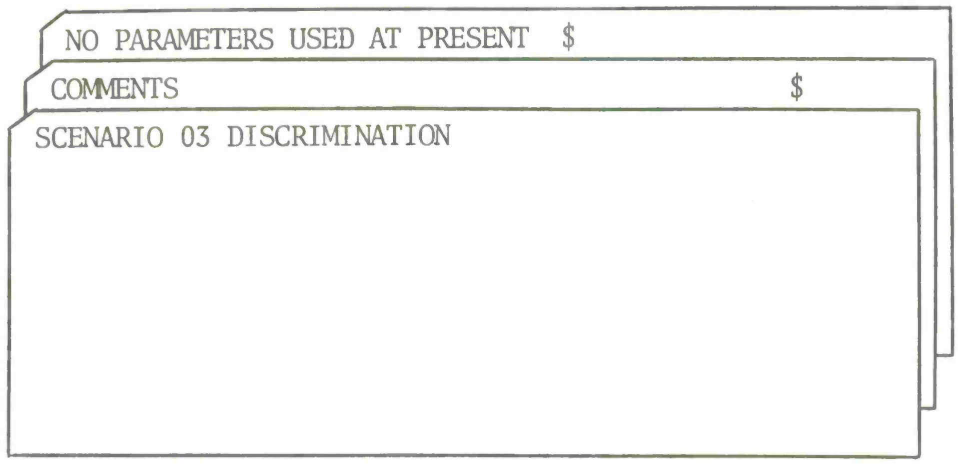
5.1.2 Tracking Scenario



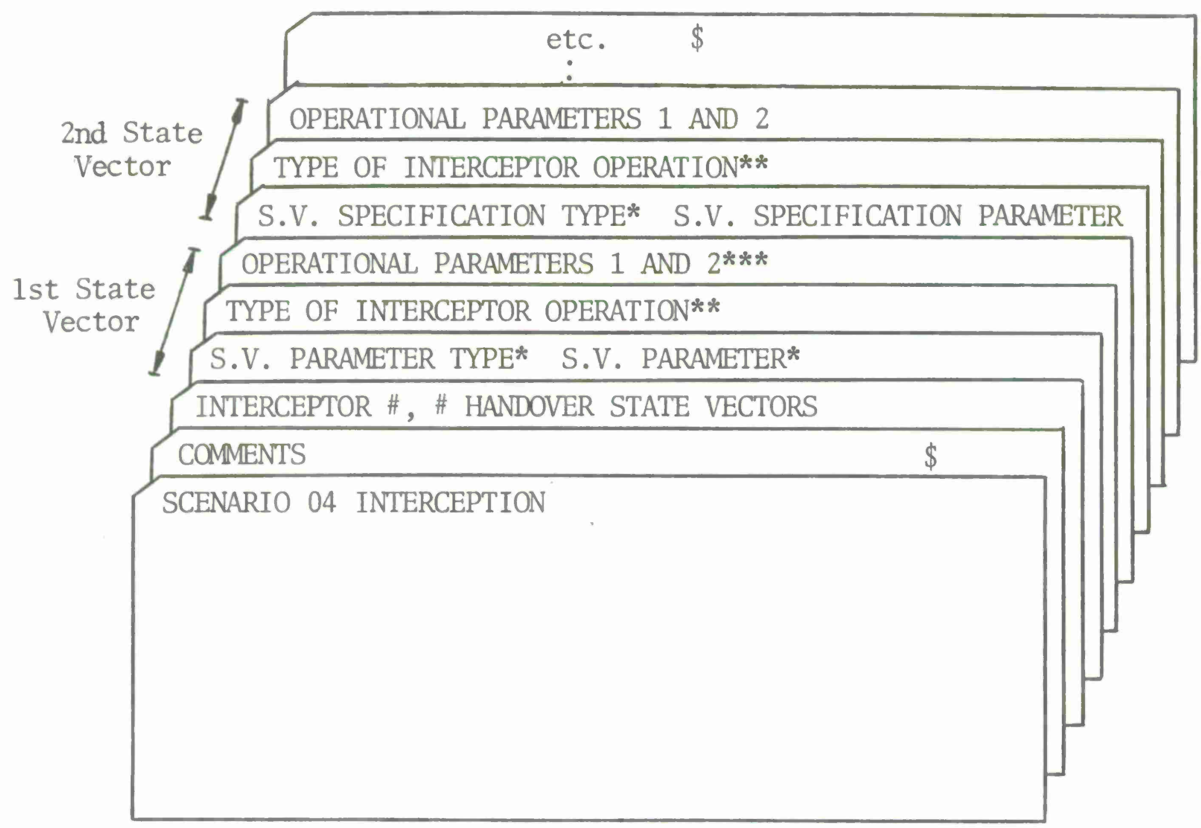
*1 = TIME, 2 = ALTITUDE, 3 = RANGE, 4 = ELEVATION

5.1.3 Discrimination Scenario Data Packet

This Scenario is not currently in use, since at present ARIES contains no discrimination algorithms. The packet is recognized, however, as explained in Section 3.1.3.



5.1.4 Interception Scenario Data Packet



*1 = Use State Vector after Specified Track Interval Number

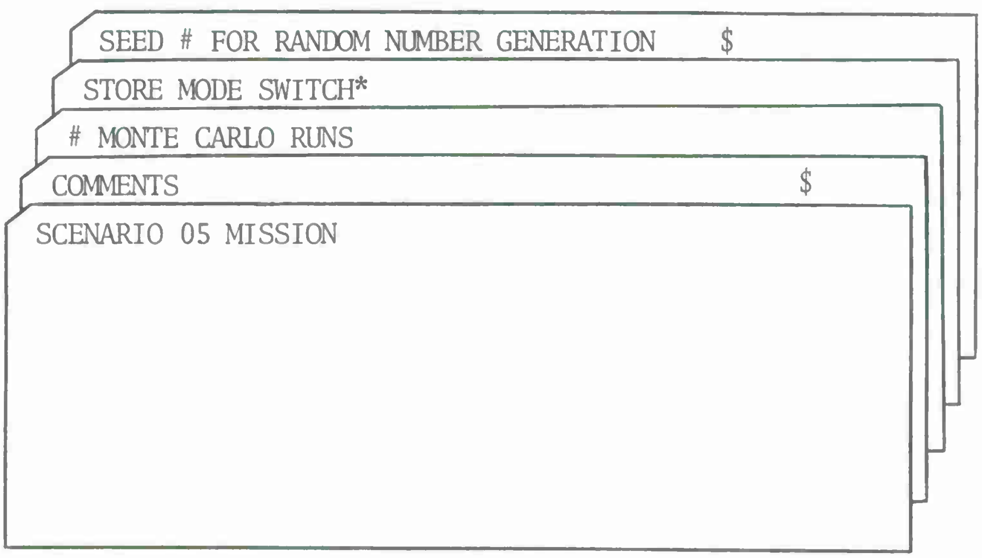
2 = Use State Vector at a Specified TAL (Seconds)
3 = Use State Vector at a Specified Altitude (Meters)

**1 = Handover Covariances, at Uniform Times After Track
2 = Handover Covariances, at Uniform Altitudes After Track
3 = Perform an Intercept at Specified Altitude

***Operational Parameter 1
For Operation Type 1, This is the DELT Between Covariance Computations
For Operation Type 2, This is the DALT Between Covariance Computations
For Operation Type 3, This is the Intercept Altitude

Operational Parameter 2
For Operation Type 1, Time Interval for Covariance Computations
For Operation Type 2, Altitude Interval for Covariance Computations
For Operation Type 3, Undefined at Present

5.1.5 Mission Scenario Data Packet



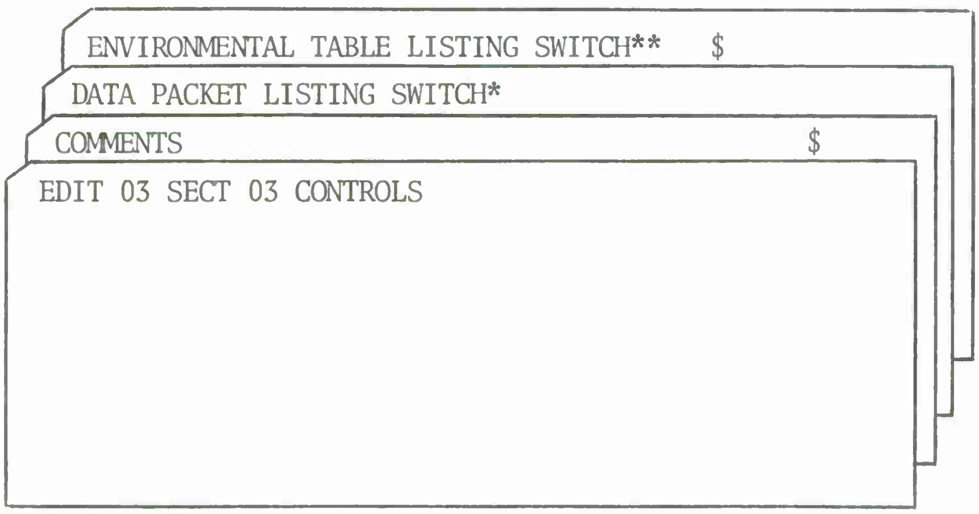
*0 = Generate new target position and orientation on every Monte Carlo run

1 = Store

5.2 EDIT Control Packets

There is potentially an EDIT controls data packet for each section of the ARIES Test Report except for Section 1. At present, however, only the Section 3, 8 and 9 EDIT controls have been defined

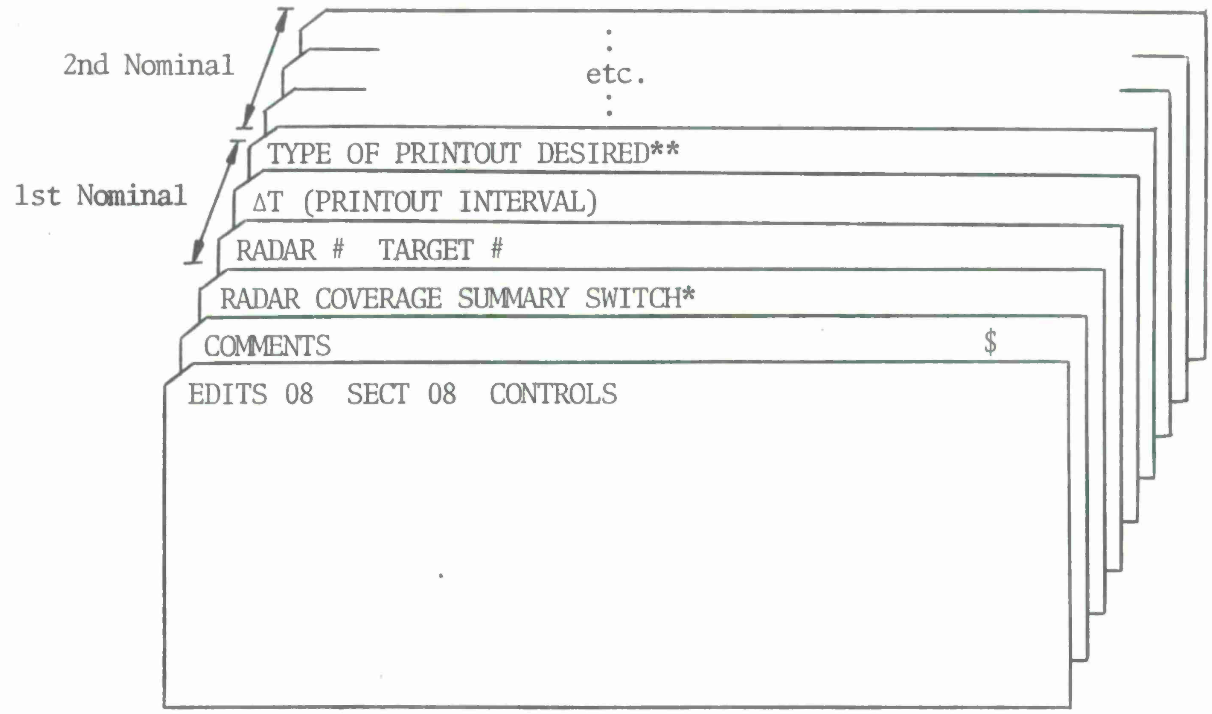
5.2.1 Section 3 EDIT Controls Data Packet



*0 = off, 1 = on

**0 = no listing, 1 = list tables to be used during ARIES Test, 2 = list all tables, whether used or not.

5.2.2 Section 8 EDIT Controls Data Packet



*0 = no summary, 1 = summary desired

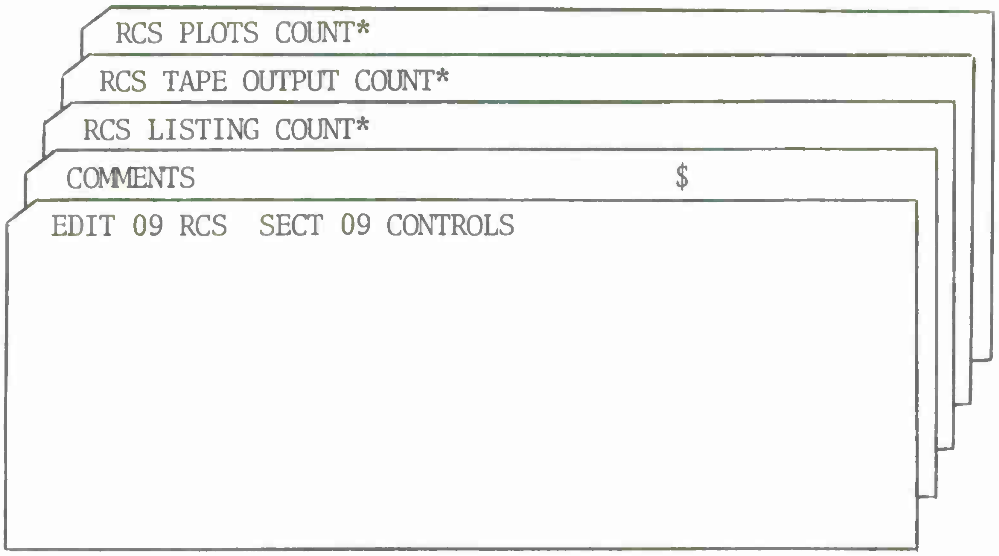
**0 = RAE position, Rates, Altitude, from 30 seconds before the target enters radar coverage, thru coverage interval.

1 = Same as type 0, except from launch to impact.

2 = Same as type 0, except RUV positions and rates.

3 = Same as type 1, except RUV positions and rates.

5.2.3 Section 09 EDIT Controls Data Packet



*Number of Monte Carlo runs for which the listing (tape, plots) are to be made, starting with Monte Carlo run No. 1.

5.3 Target Data Packets

There are eight possible target-input options available in ARIES. These options are most easily seen in Table 5.1. There are permitted the usual alphanumeric comments at the beginning of each data packet (preceding the first $ sign). Table 5.1a shows the order in which various quantities related to the target's RCS are input. Following the last input item, a $ sign is required. See the Appendix, page 10, for an example of a typical target input data packet.

TABLE 5.1a TARGET INPUT DATA PACKETS

Keyword: TARG Number: (any) Name: 4A4 Target Input Array

	ECI	XYZ	RAE	XRF	RUV	L-I,ME	L-I,LA	L-I,RA
Target Input Options:	1	2	3	4*	5*	6	7	8
Items	**Item No.**							
Option Number	1	1	1	1	1	1	1	1
Tag Time	2	2	2	2	2	X	X	X
Position	3	3	3	3	3	X	X	X
Position	4	4	4	4	4	X	X	X
Position	5	5	5	5	5	X	X	X
Rate	6	6	6	6	6	X	X	X
Rate	7	7	7	7	7	X	X	X
Rate	8	8	8	8	8	X	X	X
Launch Longitude	X	X	X	X	X	2	2	2
Latitude	X	X	X	X	X	3	3	3
Height	X	X	X	X	X	4	4	4
Impact Longitude	X	X	X	X	X	5	5	5
Latitude	X	X	X	X	X	6	6	6
Height	X	X	X	X	X	7	7	7
Angle (launch 7, reentry 8)	X	X	X	X	X	X	8	8
Reference Longitude at TAL = 0	9	X	X	X	X	X	X	X
Reference Radar Longitude	X	9	9	9	9	X	X	X
Latitude	X	10	10	10	10	X	X	X
Height	X	11	11	11	11	X	X	X
Reference Radar Bore Azimuth	X	X	X	12	12	X	X	X
Bore Elevation	X	X	X	13	13	X	X	X
Drag Table Number	10	12	12	14	14	8	9	9

*Not yet implemented

TABLE 5.1b TARGET INPUT DATA PACKETS (Cont'd)

RCS Input Options	ECI PILOT 1	LAUNCH POINT 2*	CYLINDER 3	SINUSOID 4	SPHERE 5
Option Number	1	1	1	1	1
Tag Time (same reference as state vector tag time)	2	2	2	-	-
Euler Angles (radians)	3	3	3	-	-
Euler Angles	4	4	4	-	-
Euler Angles	5	5	5	-	-
Angular Rates (radians/sec)	6	6	6	-	-
Angular Rates	7	7	7	-	-
Angular Rates	8	8	8	-	-
Moments of Inertia (kg/m^2)	9	9	9	-	-
Moments of Inertia	10	10	10	-	-
Moments of Inertia	11	11	11	-	-
RCS Table Number	12	12	-	-	-
Launch Point Longitude (radians)	-	13	-	-	-
Launch Point Latitude (radians)	-	14	-	-	-
Launch Point Height (meters)	-	15	-	-	-
Cylinder Length (meters)	-	-	12	-	-
Cylinder Radius (meters)	-	-	13	-	-
Sinusoid Peak (dbsm)	-	-	-	2	-
Sinusoid Null (dbsm)	-	-	-	3	-
Sinusoid Frequency (radians/sec)	-	-	-	4	-
Cross-section (dbsm)	-	-	-	-	2

*Not yet implemented in Subroutine TARGIN

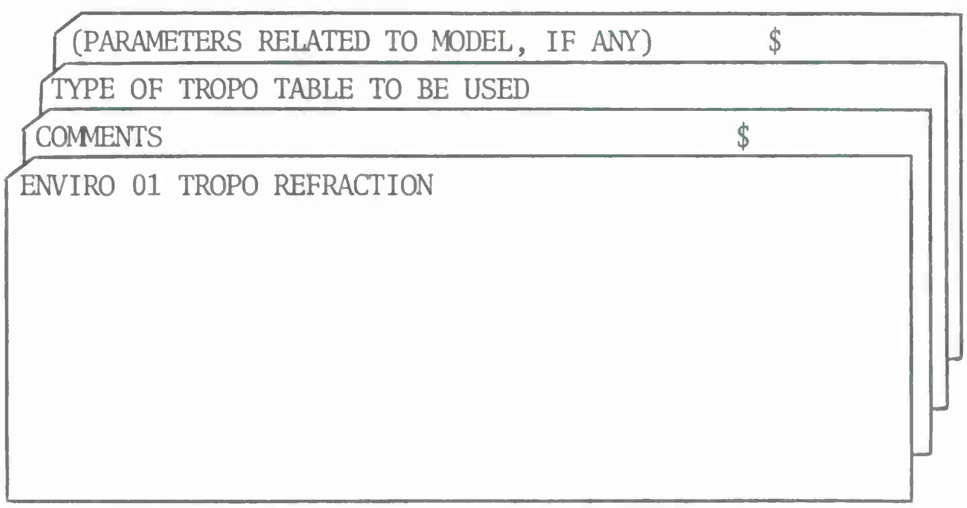
5.4 Environmental Data Packets

There are four types of packets which define the environmental models to be used during an ARIES Test Run:

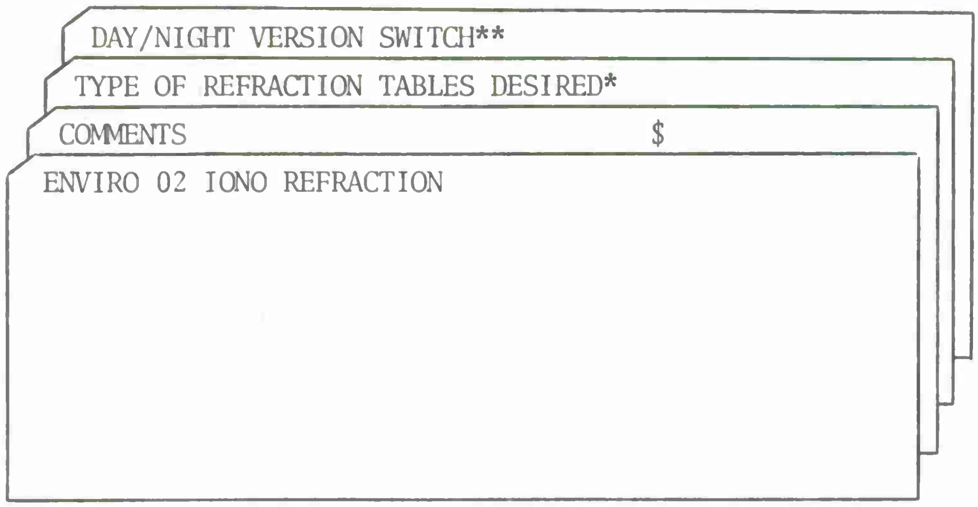
Tropospheric Refraction Data Packet
Ionospheric Refraction Data Packet
Multipath Model Data Packet
Ionospheric Scintillation Data Packet

Examples of these packets are found in the Appendix, pages 13, 15 and 18.

5.4.1 Tropospheric Refraction Data Packet



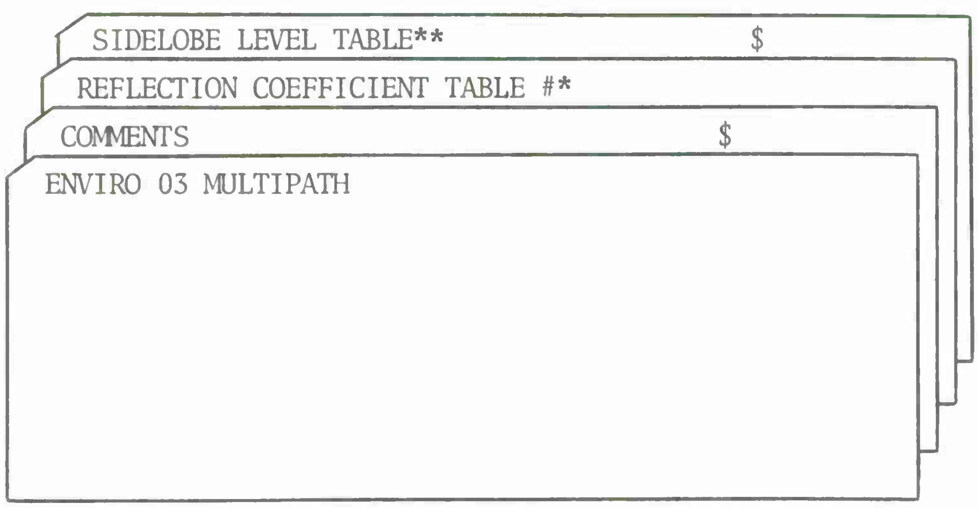
5.4.2 Ionospheric Refraction Data Packet



*1 = G.E. RAMIE Tables

**0 = Day, 1 = Night

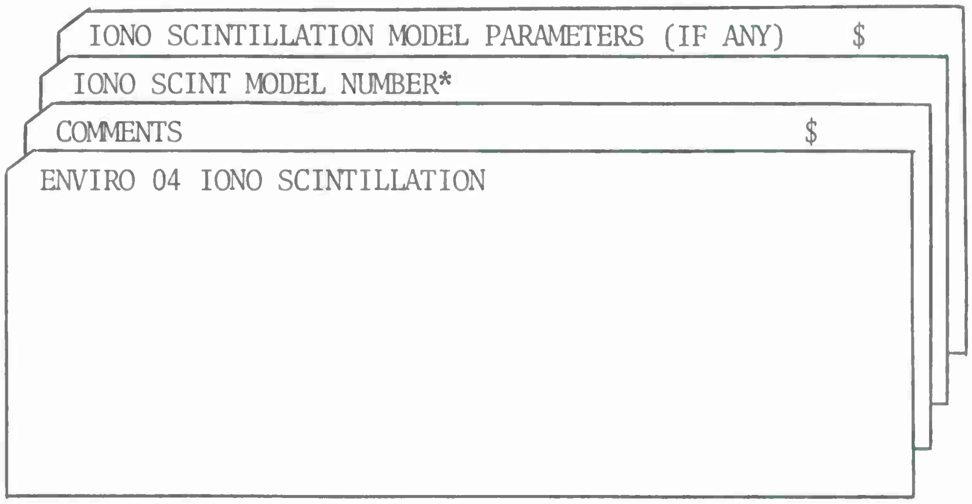
5.4.3 Multipath Data Packet



*1: use $\varepsilon = 10$

**1: use the G.E. Model

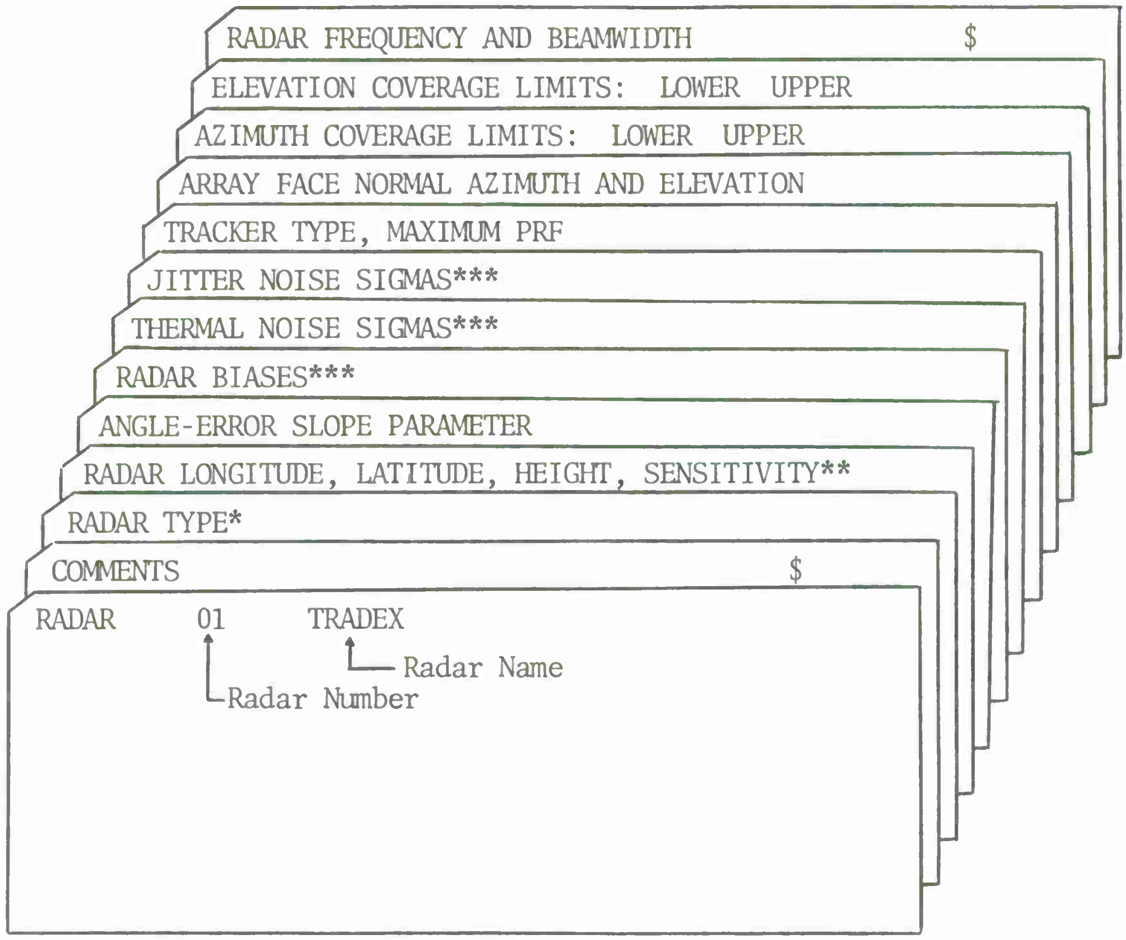
5.4.4 Ionospheric Scintillation Data Packet



*1 = Wand Model (Reference 4, described in Reference 2)

5.5 Radar Data Packets

There are two basic options in a Radar Data Packet, depending upon whether the radar is an RAE dish-type or an RUV phased-array-type. The principal differences lie in the fact that the array face normal direction and the radar coverage limits must both be specified for an RUV phased-array radar. The assumption is made by ARIES that the only coverage limitation on an RAE dish radar is that the elevation cannot become negative.



*0 = RAE (dish type), 1 = RUV (phased-array type)

**Sensitivity is defined as the range at which a 0 dbsm sphere would have an SNR of 0 db.

***Range, Traverse or U, Elevation or V.

5.6 Tracker Data Packets

The TRACKER data packets are intended to supply the user-specified parameters to tracking algorithms otherwise built into the ARIES program. At present the only "tracker" built into ARIES is the Maximum Likelihood Estimator (MLE) which puts a "best fit" trajectory through the set of radar measurements, as described in detail in Section 7 of Reference 1. This Type 1 MLE tracker requires no user-input parameters except for the number of iterations to be used in the trajectory-fitting process. For other types of trackers, there will certainly be additional "clamping" parameters, time constants, etc., over which the user will want control. This will be accomplished by a tracker data packet of the following form:

```
TRACKER PARAMETERS          $
MAXIMUM # ITERATIONS IN TRAJECTORY-FITTING PROCESS
COMMENTS                                          $
TRACKER      01      MLE TRACKER
             ↑             ↑
             |             └Tracker name
             └Tracker algorithm number
```

5.7 Discrimination Data Packets

The SCHEMA data packets are intended to supply the user-specified parameters to discrimination algorithms otherwise built into the ARIES program. At present ARIES has no built-in discrimination (other than the trivial algorithm which declares all objects in track to be threatening), and thus at present the SCHEMA data packet is not required on an ARIES Test Run. For the future, if and when some discrimination schema is plugged into ARIES, parameters associated with the schema will be specified by the user via a data packet of the following form:

```
SCHEMA PARAMETERS                    $
COMMENTS                             $
SCHEMA      03      MULLIN ALGORITHM
            ↑                ↑
            │                └─Schema name
            └─Discrimination schema number
```

5.8 Interceptor Data Packets

The INTErcept data packets are intended to supply the user-specified parameters to the interceptor models otherwise built into the ARIES Program. At present ARIES has no built in interceptor models (only handover state vector error correlation and covariances are computed, implicitly assuming a perfect intercept of the handover state vector). For the future, if and when some interceptor model is incorporated into ARIES, parameters associated with the model will be specified by the user via a data packet of the following form:

```
INTERCEPTOR MODEL PARAMETERS                $
COMMENTS                                    $
INTERCEPT     05      SPRINT
              ↑         ↑
              │         └─Interceptor name
              └─Interceptor type
```

5.9 END Card

```
END

            (Don't Forget This One)
```

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The author would like to express his appreciation to each of those Staff Members and Programmers who assisted in the growth and successful execution of the ARIES Program...

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A special commendation must be awarded Deborah Bauer, for her invaluable assistance and persistence in the preparation of this report.

REFERENCES

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2. J. L. Mannos and J. L. Katz, "The ARIES Program: Analysis and Generation of Simulated Radar Measurements," Technical Note 1975-16, Lincoln Laboratory, M.I.T. (9 July 1975), DDC AD-A01373419.

3. G. B. Morse and W. E. Courtney, "The ARIES Program: Applications and Results," private communication.

4. R. H. Wand, "Worst-Case Models for Ionospheric Scintillation," private communication to W. E. Courtney (23 April 1974).

APPENDIX

SAMPLE PAGES FROM AN ACTUAL ARIES TEST REPORT

ARIES TEST REPORT

STUDYING THE IMPACT OF ENVIRONMENTAL EFFECTS ON MLE ESTIMATOR QUALITY

12/19/75

PROGRAM VERSION 001

MARCH 28, 1974

ARIES TEST REPORT

TABLE OF CONTENTS

SECTION 1

MISSION SCENARIO, OBJECTIVES, AND CONTROL PARAMETERS

MISSION SCENARIO INPUT CARDS

THIS ARIES TEST IS BEING RUN TO CONFIRM RESULTS OBTAINED BY BILL COURTNEY USING THE REMMS OPTION OF THE G.E. RAMIE PROGRAM. TWO CASES ARE RUN HERE, ONE A LOFTED TRAJECTORY AND ONE A DEPRESSED TRAJECTORY.

BOTH TRAJECTORIES HAVE HARBIN, USSR, AS THEIR LAUNCH POINT AND NEW ORLEANS AS THEIR IMPACT POINT. THE LOFTED TRAJECTORY HAS A REENTRY ANGLE OF -40 DEGREES, WHILE THE DEPRESSED TRAJECTORY HAS A REENTRY ANGLE OF ONLY -5 DEGREES.

THE RADAR IS A PHASED ARRAY, LOCATED AT GRAND FORKS, AND ORIENTED SUCH THAT THE TARGETS ARE NEARLY ON BORESIGHT IN AZIMUTH. A MAXIMUM LIKELIHOOD ESTIMATOR IS USED TO ESTIMATE THE TARGET POSITIONS AND RATES AFTER ALL RADAR MEASUREMENTS HAVE BEEN MADE. THE PROBLEM OF POINTING THE RADAR DURING THE DATA COLLECTION PERIOD IS NOT CONSIDERED.

NO ACTUAL DISCRIMINATION OR INTERCEPTION IS REQUIRED ON THIS RUN. THE MLE STATE VECTORS ARE TO BE EXTRAPOLATED AHEAD IN TIME, BEYOND THE TIME OF THE LAST RADAR MEASUREMENT. AT 10 SECOND INTERVALS THE ERROR BETWEEN THE MLE EXTRAPOLATED ESTIMATED TARGET POSITION AND THE TRUE TARGET POSITION IS USED TO OBTAIN AN ESTIMATE OF THE HANDOVER COVARIANCE MATRIX. BY AVERAGING SUCH ESTIMATES OVER $300 MONTE CARLO RUNS, GOOD COVARIANCES ESTIMATES WILL BE OBTAINED. 0 47 $

MEASUREMENTS SCENARIO INPUT CARDS

WE WANT TO USE THE FULL GAMBIT OF MEASUREMENT NOISE COMPONENTS $ RADAR BIASES 1, RANGE-INDEPENDENT RANDOM NOISE (JITTER) 1, RANGE DEPENDENT RANDOM NOISE (THERMAL) 1, TROPOSPHERIC REFRACTION 1 WITH AN UNREMOVABLE FRACTION PT = 0.1, IONOSPHERIC REFRACTION 1 WITH AN UNREMOVABLE FRACTION PI = .3, NO MULTIPATH OR IONOSPHERIC SCINTILLATION WILL BE USED. 0 0 0 $

TRACKING SCENARIO INPUT CARDS

WHILE THE TARGET NOMINALS WILL APPEAR IN SECTION 8 DURING THE TIMES THE TARGETS ARE IN RADAR COVERAGE, WE ONLY WANT TO TRACK OVER SHORT PERIODS, AS FOLLOWS

$ FOR RADAR 1, TRACK TARGET 1 FOR 1 INTERVAL, WITH A START TIME1 OF 3000. TAL, AND A STOP TIME1 OF 3050 TAL. USE A PRF OF .83333333333333333
$

DISCRIMINATION SCENARIO INPUT CARDS

DISCRIMINATION IS NOT TO BE PERFORMED ON THIS TEST. BY DEFAULT, A TARGET IN TRACK BY ANY RADAR WILL BE CONSIDERED THREATENING. $ $

INTERCEPTION SCENARIO INPUT CARDS

$ FOR INTERCEPTOR 1, COMPUTE THE HANDOVER COVARIANCES (OPTION 1) OF ALL THREATENING OBJECTS EVERY 10 SECONDS FOR 200 SECONDS AFTER TRACK, WITH EQUIVALENT SPHERE RADII GOOD TO 0.99 PROBABILITY THAT TARGET LIES WITHIN GIVEN RADII. $

EDIT-CONTROL INPUT CARDS FOR SECTION 3

$ LIST ENVIRO INPUT CARDS (OPTION 1), AND ALSO LIST ALL TABLES, WHETHER THEY ARE USED ON THIS RUN OR NOT (OPTION 2) $

EDIT-CONTROL INPUT CARDS FOR SECTION 8

```
$ RADAR COVERAGE SUMMARY DESIRED 1
RADAR 1, TARGET 1, DT OF 5 SECONDS, TYPE 1 PRINTOUT.
RADAR 2 TARGET 2 DT OF 5 SECONDS TYPE 1 PRINTOUT.  $
```

SECTION 2

TARGET MODEL DESCRIPTIONS AND PARAMETERS

TARGET 1 INPUT CARDS HARBIN/ORLEANS40

```
$ OPTION 8 (REENTRY ANGLE LAUNCH/IMPACT)  LAUNCH FROM HARBIN,
LONGITUDE 2.199114858, LATITUDE 0.811578102, HEIGHT=0., AND
IMPACT AT NEW ORLEANS, LONGITUDE 4.712388981 LATITUDE .523598776
HEIGHT 0, WITH A REENTRY ANGLE OF FORTY DEGREES (-.698131701 RADIANS) $
```

TARGET FILE 1 HARBIN/ORLEANS40

TAL OF METRIC DATA (SEC)			0.0000
ECI POSITIONS (KM)	-2578.7143	3549.2957	4623.1133
ECI RATES (M/SEC)	-1139.1359	-1724.3565	7643.1455
ECI ACCELERATIONS (M/SEC**2)	3.9703	-5.4647	-7.1180
ALTITUDE(KM)			-.0000
LONGTITUDE (DEG AND MR)		126.00000003	2199.1148580
GEODETIC LATITUDE (DEG AND MR)		46.49999999	811.5781020
DRAG TABLE NUMBER			0.0000
TAL OF RCS DATA (SEC)			0.0000
EULER ANGLES (MR)	0.0000	0.0000	0.0000
EULER ANGLE RATES (MR/SEC)	0.0000	0.0000	0.0000
EULER ANGLE ACCELERATIONS (MR/SEC**2)	0.0000	0.0000	0.0000
MOMENTS OF INERTIA (KG/M**2)	0.0000	0.0000	0.0000
RADAR CROSS-SECTION TABLE NUMBER			0.0000
TAG TIME OF LAUNCH (SEC)			0.000000
LAUNCH LONGITUDE (DEG AND MR)		126.00000003	2199.1148580
LAUNCH GEODETIC LATITUDE (DEG AND MR)		46.49999999	811.5781020
LAUNCH ANGLE (DEG AND MR)		40.01651084	698.4198693
LAUNCH AZIMUTH (DEG AND MR)		15.59389164	272.1647523
TAL OF REENTRY (SEC)			3559.1504
REENTRY LONGITUDE (DEG AND MR)		269.78610695	4708.6558423
REENTRY GEODETIC LATITUDE (DEG AND MR)		30.95511345	540.2686500
REENTRY ANGLE (DEG AND MR)		-40.00000004	-698.1317015
TAL OF IMPACT (SEC)			3577.4062
IMPACT LONGITUDE (DEG AND MR)		270.00000316	4712.3890354
IMPACT GEODETIC LATITUDE (DEG AND MR)		30.00000609	523.5988819
IMPACT ANGLE (DEG AND MR)		-39.99322274	-698.0134154

SECTION 3

ENVIRONMENTAL MODEL DESCRIPTIONS AND PARAMETERS

TROPOSPHERIC MODEL INPUT CARDS

$ USE TROPOSPHERIC REFRACTION TABLES TYPE 1 (GE RAMIE TABLES) $

TROPOSPHERIC REFRACTION TABLE 1 -- (GE RAMIE)

TO COMPUTE THE RANGE AND ELEVATION REFRACTION, ONE PERFORMS TWO TABLE LOOK-UPS, THE FIRST TO GET DR AND DE AS FUNCTIONS OF ELEVATION, THE SECOND TO GET A WEIGHTING FACTOR (A FUNCTION OF ALTITUDE) WHICH IS USED TO WEIGHT THE DR AND DE NUMBERS OBTAINED IN THE FIRST TABLE LOOK-UP. THUS

DR = DR(ELEVATION)*FACTOR1(ALTITUDE)
DE = DE(ELEVATION)*FACTOR2(ALTITUDE)

ELEVATION (MR)	DR(ELEV) (M)	DE(ELEV) (MR)
0.000	107.869	12.280
17.453	69.159	8.580
34.907	49.256	6.250
69.813	30.328	3.930
104.720	21.549	2.810
139.626	16.916	2.200
174.533	13.503	1.760
261.799	9.205	1.180
349.066	6.980	.870
523.599	4.816	.550
698.132	3.962	.400
872.665	3.139	.270
1047.198	2.743	.180
1221.730	2.530	.100
1396.263	2.438	.050
1483.530	2.408	.030

ALTITUDE (KM)	FACTOR1(ALT)	FACTOR2(ALT)
0.0	0.000	0.000
1.0	.140	.080
2.0	.260	.140
3.0	.350	.200
6.0	.590	.330
10.0	.790	.440
20.0	.950	.600
30.0	.970	.720
60.0	.980	.830
100.0	.981	.890
300.0	.990	.940
600.0	.995	.960
1000.0	1.000	.980
5000.0	1.000	1.000

IONOSPHERIC MODEL INPUT CARDS

```
$ USE IONOSPHERIC REFRACTION TABLES TYPE 1 (GE RAMIE TABLES),
THE DAY-TIME VERSION 0 $
```

IONOSPHERIC REFRACTION TABLE 1 -- DAY (GE RAMIE)

TO COMPUTE THE RANGE AND ELEVATION REFRACTION, ONE PERFORMS TWO TABLE LOOK-UPS, THE FIRST TO GET DR AND DE AS FUNCTIONS OF ELEVATION, THE SECOND TO GET A WEIGHTING FACTOR (A FUNCTION OF ALTITUDE) WHICH IS USED TO WEIGHT THE DR AND DE NUMBERS OBTAINED IN THE FIRST TABLE LOOK-UP. THUS

DR = DR(ELEVATION)*FACTOR1(ALTITUDE)
DE = DE(ELEVATION)*FACTOR2(ALTITUDE)

ELEVATION (MR)	DR(ELEV) (M)	DE(ELEV) (MR)
0.000	229.880	.387
17.453	229.484	.398
34.907	228.387	.406
69.813	224.089	.413
104.720	217.566	.408
139.626	209.459	.395
174.533	200.436	.377
261.799	176.997	.325
349.066	155.631	.273
523.599	119.482	.188
698.132	100.584	.138
872.665	88.483	.101
1047.198	79.248	.071
1221.730	73.762	.045
1396.263	71.110	.021
1483.530	68.885	.010

ALTITUDE (KM)	FACTOR1(ALT)	FACTOR2(ALT)
100.0	0.000	0.000
150.0	.030	.120
200.0	.090	.230
300.0	.390	.620
400.0	.750	.950
500.0	.910	1.000
700.0	.990	.960
1000.0	1.000	.890
2000.0	1.000	.780
5000.0	1.000	.600

IONOSPHERIC REFRACTION TABLE 1 -- NIGHT (GE RAMIE)

TO COMPUTE THE RANGE AND ELEVATION REFRACTION, ONE PERFORMS TWO TABLE LOOK-UPS, THE FIRST TO GET DR AND DE AS FUNCTIONS OF ELEVATION, THE SECOND TO GET A WEIGHTING FACTOR (A FUNCTION OF ALTITUDE) WHICH IS USED TO WEIGHT THE DR AND DE NUMBERS OBTAINED IN THE FIRST TABLE LOOK-UP. THUS

DR = DR(ELEVATION)*FACTOR1(ALTITUDE)
DE = DE(ELEVATION)*FACTOR2(ALTITUDE)

ELEVATION (MR)	DR(ELEV) (M)	DE(ELEV) (MR)
0.000	64.587	.116
17.453	64.465	.120
34.907	64.130	.122
69.813	62.850	.126
104.720	60.899	.125
139.626	58.491	.122
174.533	55.778	.117
261.799	48.859	.101
349.066	42.642	.085
523.599	34.138	.062
698.132	27.432	.045
872.665	23.805	.030
1047.198	21.336	.021
1221.730	20.117	.013
1396.263	19.050	.006
1483.530	18.288	.003

ALTITUDE (KM)	FACTOR1(ALT)	FACTOR2(ALT)
100.0	0.000	0.000
150.0	.005	.030
200.0	.090	.170
300.0	.590	.820
400.0	.860	.990
500.0	.950	.990
700.0	.995	.920
1000.0	1.000	.840
2000.0	1.000	.760
5000.0	1.000	.710

MULTIPATH MODEL INPUT CARDS

$ USE MULTIPATH TABLE 1 $

MULTIPATH TABLE 1 (EPSILON = 10)

ELEVATION (MR)	REFLECTION COEFFICIENT
8.727	.96883000
34.907	.88430000
61.087	.81100000
87.266	.74674000
113.446	.68984000
139.626	.63905000
165.806	.59337000
191.986	.55203000
218.166	.51440000
244.346	.47999000
287.979	.42867000
331.613	.38364000
375.246	.34380000
418.879	.30828000
462.512	.27642000
506.145	.24772000
549.779	.22176000
593.412	.19819000
637.045	.17675000
680.678	.15721000
724.312	.13937000
794.125	.11399000
881.391	.08702700
968.658	.06463000
1055.924	.04619800
1134.464	.03262000
1221.730	.02055900
1308.997	.01143200
1396.263	.00504200
1483.530	.00127450
1570.796	.00027296

SECTION 4

RADAR MODEL DESCRIPTIONS AND PARAMETERS

RADAR 1 INPUT CARDS GRAND FORKS 336A

```
$ PHASED ARRAY (TYPE 1),LONGITUDE 4.590215933 RADIANS,
LATITUDE .8377580410 RADIANS, HEIGHT 0.
REFERENCE RANGE (SENSITIVITY) 15927200. METERS, MONOPULSE NOT USED (0),
RADAR BIASES  6.096, .00004, .00004 (METERS,SINES,SINES),
THERMAL SIGMAS  6.096, .00011, .00071
JITTER SIGMAS  4.572, .00013, .00085
TRACKER TYPE 1 (MAX-LIKELIHOOD ESTIMATOR  ),MAX PRF IS 3000. HZ.
BORESIGHT AZIMUTH IS 5.864306287 RADIANS, ELEVATION .4363323130 .
AZIMUTH COVERAGE LIMITS ARE 4.817108736 TO .6283185307 RADIANS.
ELEVATION COVERAGE LIMITS ARE .008726646260 TO 1.570796327 RADIANS.
RADAR FREQUENCY IS 1300000000 HZ, BEAMWIDTH IS .008726646260 RADIANS
$
```

RADAR FILE 1 GRAND FORKS 336A

RADAR TYPE		PHASED ARRAY (RUV)
RADAR LONGITUDE (DEG AND MR)	263.0000	4590.2159
RADAR GEODETIC LATITUDE (DEG AND MR)	48.0000	837.7580
RADAR HEIGHT ABOVE WGS-66 ELLIPSOIDAL EARTH MODEL (M)		0.0000
SENSITIVITY: REFERENCE RANGE (KM)		15927.2000
MONOPULSE SURFACE TABLE NUMBER		0.0000
RANGE BIAS (M)		6.0960
TRAVERSE BIAS (MS)		.0400
ELEVATION BIAS (MS)		.0400
RANGE-DEPENDENT MEASUREMENT NOISE STANDARD DEVIATIONS		
RANGE SIGMA (M)		6.0960
TRAVERSE SIGMA (MS)		.1100
ELEVATION SIGMA (MS)		.7100
RANGE-INDEPENDENT MEASUREMENT NOISE STANDARD DEVIATIONS		
RANGE SIGMA (M)		4.5720
TRAVERSE SIGMA (MS)		.1300
ELEVATION SIGMA (MS)		.8500
RADAR FREQUENCY (MHZ)		1300.0000
RADAR BEAMWIDTH (DEG AND MR)	.50000000	8.7266463
TRACKING ALGORITHM NUMBER		1.0000
MAXIMUM RADAR PRF (HZ)		3000.0000
AZIMUTH DIRECTION OF BORESIGHT (DEG AND MR)	336.0000	5864.3063
ELEVATION DIRECTION OF BORESIGHT (DEG AND MR)	25.0000	436.3323
LOWER LIMIT OF AZIMUTH COVERAGE (DEG AND MR)	276.0000	4817.1087
UPPER LIMIT OF AZIMUTH COVERAGE (DEG AND MR)	36.0000	628.3185
LOWER LIMIT OF ELEVATION COVERAGE (DEG AND MR)	.5000	8.7266
UPPER LIMIT OF ELEVATION COVERAGE (DEG AND MR)	90.0000	1570.7963

TRANSFORMATION FROM ECF TO RADAR XYZ COORDINATES

.99254615	-.12186934	0.00000000	0.0
.09056657	.73760554	.66913061	-.0
-.08154651	-.66414301	.74314483	-6373417.0

RADAR 2 INPUT CARDS GRAND FORKS 336B

```
$ PHASED ARRAY (TYPE 1),LONGITUDE 4.590215933 RADIANS,
LATITUDE .8377580410 RADIANS, HEIGHT 0.
REFERENCE RANGE (SENSITIVITY) 15927200. METERS, MONOPULSE NOT USED (0),
RADAR BIASES  6.096, .00004, .00004 (METERS,SINES,SINES),
THERMAL SIGMAS  6.096, .00011, .00011
JITTER SIGMAS  4.572, .00013, .00013
TRACKER TYPE 1 (MAX-LIKELIHOOD ESTIMATOR  ),MAX PRF IS 3000. HZ.
BORESIGHT AZIMUTH IS 5.864306287 RADIANS, E E A ION^.4363323130^.
AZIMUTH COVERAGE LIMITS ARE 4.817108736 TO .6283185307 RADIANS.
ELEVATION COVERAGE LIMITS ARE .008726646260  0 A^570 9 2  - D^^  H^
RADAR FREQUENCY IS 1300000000 HZ, BEAMWIDTH IS .008726646260-RADIANS
$
```

RADAR FILE 2 GRAND FORKS 336B

RADAR TYPE		PHASED ARRAY (RUV)
RADAR LONGITUDE (DEG AND MR)	263.0000	4590.2159
RADAR GEODETIC LATITUDE (DEG AND MR)	48.0000	837.7580
RADAR HEIGHT ABOVE WGS-66 ELLIPSOIDAL EARTH MODEL (M)		0.0000
SENSITIVITY: REFERENCE RANGE (KM)		15927.2000
MONOPULSE SURFACE TABLE NUMBER		0.0000
RANGE BIAS (M)		6.0960
TRAVERSE BIAS (MS)		.0400
ELEVATION BIAS (MS)		.0400
RANGE-DEPENDENT MEASUREMENT NOISE STANDARD DEVIATIONS		
RANGE SIGMA (M)		6.0960
TRAVERSE SIGMA (MS)		.1100
ELEVATION SIGMA (MS)		.1100
RANGE-INDEPENDENT MEASUREMENT NOISE STANDARD DEVIATIONS		
RANGE SIGMA (M)		4.5720
TRAVERSE SIGMA (MS)		.1300
ELEVATION SIGMA (MS)		.1300
RADAR FREQUENCY (MHZ)		.0000
RADAR BEAMWIDTH (DEG AND MR)	114.59155903	2000.0000000
TRACKING ALGORITHM NUMBER		1.0000
MAXIMUM RADAR PRF (HZ)		3000.0000
AZIMUTH DIRECTION OF BORESIGHT (DEG AND MR)	336.0000	5864.3063
ELEVATION DIRECTION OF BORESIGHT (DEG AMD MR)	25.0000	436.3323
LOWER LIMIT OF AZIMUTH COVERAGE (DEG AND MR)	276.0000	4817.1087
UPPER LIMIT OF AZIMUTH COVERAGE (DEG AND MR)	36.0000	628.3185
LOWER LIMIT OF ELEVATION COVERAGE (DEG AND MR)	.5000	8.7266
UPPER LIMIT OF ELEVATION COVERAGE (DEG AND MR)	32658.5943	*0000.0000

TRANSFORMATION FROM ECF TO RADAR XYZ COORDINATES

.99254615	-.12186934	0.00000000	0.0
.09056657	.73760554	.66913061	-.0
-.08154651	-.66414301	.74314483	-6373417.0

SECTION 6

DISCRIMINATION SCHEMA DESCRIPTIONS AND PARAMETERS

SECTION 7

INTERCEPTOR MODEL DESCRIPTIONS AND PARAMETERS

SECTION 8

RADAR COVERAGE REPORT AND PRE-MISSION NOMINALS

RADAR COVERAGE SUMMARY REPORT

TARGET 1 AS VIEWED BY RADAR 1

TAL	RANGE	AZ	EL	RDOT	ADOT	EDOT	ALTITUDE	TAGTIME
30.000	4.126	3146.351	515.986	165.609	-.046	-45.491	2.037	29.995
44.000	6.797	3146.222	-1.302	220.298	.005	-30.525	-.005	43.995

TARGET 1 AS VIEWED BY RADAR 1

TAL	RANGE	U	V	RDOT	UDOT	VDOT	ALTITUDE	TAGTIME
899.000	7130.113	5909.124	-9.129	-983.163	.106	.605	3146.526	899.000
904.000	7125.191	5909.653	-6.106	-985.673	.106	.604	3157.281	904.000
909.000	7120.257	5910.180	-3.090	-988.222	.105	.603	3167.971	909.000
914.000	7115.309	5910.707	-.079	-990.812	.105	.602	3178.594	914.000
919.000	7110.348	5911.233	2.926	-993.440	.105	.600	3189.152	919.000
924.000	7105.375	5911.757	5.926	-996.108	.105	.599	3199.644	924.000
929.000	7100.387	5912.280	8.920	-998.815	.105	.598	3210.070	929.000
934.000	7095.386	5912.803	11.908	-1001.560	.104	.597	3220.431	934.000
939.000	7090.372	5913.324	14.890	-1004.344	.104	.596	3230.726	939.000
944.000	7085.343	5913.845	17.868	-1007.166	.104	.595	3240.956	944.000
949.000	7080.300	5914.364	20.839	-1010.026	.104	.594	3251.121	949.000
954.000	7075.243	5914.882	23.805	-1012.925	.104	.593	3261.220	954.000
959.000	7070.171	5915.400	26.766	-1015.861	.103	.592	3271.255	959.000
964.000	7065.084	5915.916	29.721	-1018.835	.103	.591	3281.224	964.000
969.000	7059.982	5916.431	32.671	-1021.846	.103	.589	3291.129	969.000
974.000	7054.865	5916.946	35.616	-1024.894	.103	.588	3300.969	974.000
979.000	7049.733	5917.459	38.555	-1027.980	.103	.587	3310.744	979.000
984.000	7044.586	5917.972	41.489	-1031.102	.102	.586	3320.454	984.000
989.000	7039.422	5918.483	44.418	-1034.261	.102	.585	3330.100	989.000
994.000	7034.243	5918.994	47.342	-1037.457	.102	.584	3339.682	994.000
999.000	7029.047	5919.503	50.260	-1040.689	.102	.583	3349.199	999.000
1004.000	7023.836	5920.012	53.173	-1043.957	.102	.582	3358.652	1004.000
1009.000	7018.608	5920.520	56.081	-1047.262	.101	.581	3368.040	1009.000
1014.000	7013.363	5921.027	58.984	-1050.602	.101	.580	3377.365	1014.000
1019.000	7008.102	5921.533	61.882	-1053.978	.101	.579	3386.625	1019.000
1024.000	7002.823	5922.038	64.775	-1057.389	.101	.578	3395.822	1024.000
1029.000	6997.528	5922.542	67.663	-1060.836	.101	.577	3404.955	1029.000
1034.000	6992.215	5923.045	70.546	-1064.317	.101	.576	3414.024	1034.000
1039.000	6986.885	5923.548	73.424	-1067.834	.100	.575	3423.029	1039.000
1044.000	6981.537	5924.049	76.298	-1071.386	.100	.574	3431.971	1044.000
1049.000	6976.171	5924.550	79.166	-1074.972	.100	.573	3440.849	1049.000
1054.000	6970.787	5925.049	82.030	-1078.593	.100	.572	3449.664	1054.000
1059.000	6965.385	5925.548	84.888	-1082.248	.100	.571	3458.415	1059.000
1064.000	6959.964	5926.046	87.742	-1085.937	.100	.570	3467.103	1064.000
1069.000	6954.525	5926.544	90.591	-1089.661	.099	.569	3475.728	1069.000
1074.000	6949.068	5927.040	93.436	-1093.418	.099	.568	3484.290	1074.000
1079.000	6943.591	5927.535	96.276	-1097.209	.099	.568	3492.788	1079.000
1084.000	6938.095	5928.030	99.111	-1101.033	.099	.567	3501.224	1084.000
1089.000	6932.581	5928.524	101.942	-1104.891	.099	.566	3509.597	1089.000
1094.000	6927.046	5929.017	104.768	-1108.782	.099	.565	3517.906	1094.000
1099.000	6921.493	5929.509	107.589	-1112.706	.098	.564	3526.153	1099.000
1104.000	6915.919	5930.001	110.406	-1116.663	.098	.563	3534.338	1104.000
1109.000	6910.326	5930.491	113.219	-1120.653	.098	.562	3542.459	1109.000
1114.000	6904.713	5930.981	116.027	-1124.676	.098	.561	3550.519	1114.000
1119.000	6899.079	5931.470	118.830	-1128.731	.098	.560	3558.515	1119.000
1124.000	6893.425	5931.959	121.630	-1132.818	.098	.559	3566.450	1124.000
1129.000	6887.751	5932.446	124.425	-1136.937	.097	.559	3574.321	1129.000
1134.000	6882.056	5932.933	127.215	-1141.089	.097	.558	3582.131	1134.000
1139.000	6876.340	5933.419	130.001	-1145.272	.097	.557	3589.878	1139.000
1144.000	6870.603	5933.904	132.783	-1149.487	.097	.556	3597.564	1144.000

RADAR LATITUDE= .87 LONGITUDE= .17

SECTION 9

MEASUREMENTS QUALITY REPORT

SECTION 10

TRACKING PERFORMANCE REPORT

SQUARED RANGE RESIDUALS = 3.8913318815
SQUARED AZIMUTH RESIDUALS = .0000108586
SQUARED ELEVATION RESIDUALS = .0000916367
BASED ON 50 MONTE CARLO RUNS

SECTION 11

DISCRIMINATION PERFORMANCE REPORT

OBJECTS IDENTIFIED AS THREATENING

TARGET 1 AS TRACKED BY RADAR 1

SECTION 12

INTERCEPTOR PERFORMANCE REPORT

COVARIANCES OF HANDOVER POINT
FROM RADAR 1 FOR TARGET 1

TAL = 3149.200

.19808E+06		ELLIPSE SIGMAS=	.29106E+06	.35588E+04	.14049E+06
-.34753E+05	.12582E+06		EQUIVALENT SPHERE RADIUS=		.13934E+04
-.72747E+05	.10962E+06	.11121E+06		FOR PROBABILITY=	.99000E+00
.10095E+04	.19466E+03	.22332E+02	.82540E+01		
.48830E+03	.22372E+03	-.71365E+02	.15039E+01	.54829E+01	
-.79725E+02	.37388E+03	.27754E+03	.13663E+00	.18013E+01	.14450E+01

TAL = 3159.200

.21908E+06		ELLIPSE SIGMAS=	.30080E+06	.47091E+04	.16130E+06
-.27770E+05	.13083E+06		EQUIVALENT SPHERE RADIUS=		.14205E+04
-.73303E+05	.11282E+06	.11690E+06		FOR PROBABILITY=	.99000E+00
.10904E+04	.20988E+03	.24235E+02	.82387E+01		
.50371E+03	.27774E+03	-.54203E+02	.14986E+01	.54842E+01	
-.78012E+02	.39093E+03	.29115E+03	.13668E+00	.17971E+01	.14391E+01

TAL = 3169.200

.24169E+06		ELLIPSE SIGMAS=	.31223E+06	.60837E+04	.18316E+06
-.20482E+05	.13693E+06		EQUIVALENT SPHERE RADIUS=		.14529E+04
-.73823E+05	.11635E+06	.12286E+06		FOR PROBABILITY=	.99000E+00
.11710E+04	.22500E+03	.26150E+02	.82219E+01		
.51905E+03	.33174E+03	-.37136E+02	.14930E+01	.54853E+01	
-.76323E+02	.40788E+03	.30466E+03	.13672E+00	.17924E+01	.14327E+01

TAL = 3179.200

.26591E+06		ELLIPSE SIGMAS=	.32557E+06	.76961E+04	.20583E+06
-.12890E+05	.14410E+06		EQUIVALENT SPHERE RADIUS=		.14906E+04
-.74306E+05	.12023E+06	.12909E+06		FOR PROBABILITY=	.99000E+00
.12512E+04	.23999E+03	.28079E+02	.82037E+01		
.53432E+03	.38573E+03	-.20170E+02	.14870E+01	.54863E+01	
-.74658E+02	.42470E+03	.31806E+03	.13673E+00	.17871E+01	.14259E+01

TAL = 3189.200

.29173E+06		ELLIPSE SIGMAS=	.34116E+06	.95574E+04	.22895E+06
-.49965E+04	.15236E+06		EQUIVALENT SPHERE RADIUS=		.15334E+04
-.74754E+05	.12444E+06	.13558E+06		FOR PROBABILITY=	.99000E+00
.13309E+04	.25487E+03	.30021E+02	.81841E+01		
.54950E+03	.43969E+03	-.33137E+01	.14806E+01	.54873E+01	
-.73016E+02	.44138E+03	.33134E+03	.13674E+00	.17812E+01	.14187E+01

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ARIES is a system simulation computer program developed by Lincoln Laboratory to study radar tracking and command-guided intercepts in a realistic radar environment. This report is the first in a series of three, and provides a broad operational perspective on the ARIES Program while avoiding those mathematical details to be found in subsequent reports in the series. Model parameters and options available to the engineer are presented, together with sufficient program structure and control information to enable a programmer to execute the ARIES Program.